SİVAS BİLİM VE TEKNOLOJİ ÜNİVERSİTESİ









SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH - IV

MAY 30-31, 2025 / SIVAS, TÜRKİYE

CONFERENCE PROCEEDINGS BOOK

EDITORS

Prof. Dr. Kağan KÖKTEN

Assoc. Prof. Dr. Seyithan SEYDOŞOĞLU

SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH-IV

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adopted by Mariam Rasulan

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SIVAS INTERNATIONAL CONFERENCE ON
SCIENTIFIC AND INNOVATION RESEARCH-IV

SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH-IV

May 30 - 31, 2025
Sivas, TÜRKİYE

PROCEEDINGS BOOK
(Abstracts & Full Texts)

EDITORS

Prof. Dr. Kağan KÖKTEN

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SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH-IV

EVALUATION PROCESS and POLICIES

All applications have undergone double blind peer review process. In addition, each paper was accepted and the process of publishing in the book was carried out through editorial oversight. The published papers were presented and discussed at the meeting.

Full texts and abstracts published in accordance with the Symposium Policy have been prepared in accordance with ethical rules and APA standards. Authors of all papers are both ethically and legally responsible.

PARTICIPANTS COUNTRIES

Türkiye, Albania, Algeria, Azerbaijan, Bangladesh, Bulgaria, Ethiopia, Ghana, Hungary, India, Iran, Iraq, Jordan, Kosovo, Kyrgyzstan, Morocco, Nigeria, Oman, Pakistan, Philippines, Portugal, Romania, Russia, Slovenia, Spain, South Africa, Tunusia

TOTAL ACCEPTED ARTICLES: 366

The Number of Accepted Papers from Türkiye: 179
The Number of Accepted Full Papers from Other Countries: 187
The Number of Total Papers: 366

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SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH-IV

May 30 - 31, 2025
Sivas, TÜRKİYE

SYMPOSIUM SCHEDULE

4th SIVAS INTERNATIONAL CONFERENCE ON SCIENTIFIC AND INNOVATION RESEARCH

MAY 30-31. 2025 / SIVAS. TÜRKİYE

Sivas University of Science and Technology



CONFERENCE PROGRAM

Zoom Meeting ID: 860 5266 6988 | Passcode: 303132

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-Opening Speech-

Date: 30.05.2025

Ankara Time: 09.00 - 10.30

Sivas Science and Technology University

***

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Vice Rector of Sivas University Of Science and Technology

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- The application works on tablets, phones and PCs.
- The participant must be connected to the session 5 minutes before the presentation time.
- All congress participants can connect live and listen to all sessions.
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

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***

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CONGRESS LANGUAGES: English and All Turkish Dialects

30.05.2025 / Session-1 / Hall-1

Ankara Local Time: 10:30-12:30

Sivas University of Science and Technology

HEAD OF SESSION: Prof. Dr. Emre BİÇER

Authors	Affiliation	Presentation title
Murat DEMİR	Muş Alparslan University	Using Artificial Afterimage Algorithm for Rainfall Prediction
Mehmet Yasin UZUN Elifnur ŞİMŞEK	Sivas University of Science and Technology	The Impact of Local Artificial Intelligence Models on High School Students' Exam Preparation Process: An Evaluation on Token Velocity and Achievement Performance
Nurhan GÜNEŞ Mustafa YILMAZ	Sivas University of Science and Technology	A Comparative Analysis of Efficiency Metrics in Cvrptw Sets with Varying Numbers of Delivery Points
Tunahan GÜDER Kali GÜRKAHRAMAN	Kastamonu University	Comparative Analysis of Gan-Based Text-to-Image Models and Proposal of a Modified Galip Architecture
Muhammed Taha YILDIZ Ahmet YÜCEL	Sivas University of Science and Technology	Effect of Boron Carbide Reinforcement on the Wear Performance of Ni–Mo Alloyed Steel Produced by Powder Metallurgy
Rahmi CANPOLAT Esra KAYAŞ ALKIŞ Fatih ÖZAYDIN Osman MAVUŞ Ebru YABAŞ	ESTAŞ A.Ş, Gloves Manager	Antineoplastic Production of Drug Resistant Gloves
Yonca ALTINDAL	Balıkesir University	The Echo of Escape from Reality in Digital Cinema: Interpreting the Sociology of The Dream Movie
Sefa SEZGİN Erdal Anıl YILDIZ Ayşegül ARI Ahmet AVCI	ESTAŞ A.Ş. ES-3 Manager	Implementation of the Carburizing Heat Treatment Process on Sint D11 and Sint D32 Materials a Comparative Analysis of the Results
Berke Can TURAN Nurhan GÜNEŞ Hüsnü Deniz BAŞDEMİR	Sivas University of Science and Technology	Material-Aware Line-of-Sight Detection in Indoor Environments Using Ray Tracing and Received Signal Strength Analysis

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

30.05.2025 / Session-1 / Hall-2

Ankara Local Time: 10:30-12:30

Sivas University of Science and Technology

HEAD OF SESSION: Prof. Dr. Kağan KÖKTEN

Authors	Affiliation	Presentation title
Fatma ÇELİK BAYRAM Nisanur YILDIZELİ	Sivas Cumhuriyet University	Migration Phenomenon in The Context of The Economic Impacts of the Climate Crisis
Kübra ASLAN	Sivas Cumhuriyet University	Hybrid Management in Healthcare
Kübra ASLAN	Sivas Cumhuriyet University	The Innovative Face of Health in the Age of Digital Transformation
Fatma ÇELİK BAYRAM Fatma BOZ	Sivas Cumhuriyet University	Impacts of Climate Crisis and Migration on Food Security: Policy and Strategic Approaches for Sustainability
Ceren Barlas Ayşen BARUT USLU Fatma ÇAĞLIDABAKGİL Meltem DAĞDELEN	Sivas Numune Hospital	A Comparative Dosimetric Study Using Field-In-Field, Intensity Modulated and Volumetric Arc Modulated Radiotherapy Techniques in Terms of Cardiac Substructures Exposure for Left-Sided Breast Cancer Radiotherapy
Şevval Sultan COŞAR Ayşegül ÖZGÜLDÜ Buse YILDIZ Gül KADAN	Cankiri Karatekin University	The Effect of a Healthy Nutrition Program on Obesity, Self-Esteem and Identity Development for High School Students
Sena DOĞAN CANDAN Gülay DEMİR Hanım Eda GÖKTAŞ	Sivas Cumhuriyet University	Bibliometric Analysis of Studies on the Effects of Pilates Exercises on Chronic Pain Management
Mücahit Emin KARAGÖZ Barış KAVASOĞULLARI Mehmet Nurullah ÖNEL Ali Suat YILDIZ Emre BİÇER	Sivas University of Science and Technology	Experimental Analysis of Phase Change Material Based Battery Thermal Management System for Different Environmental and Discharge Conditions

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30.05.2025 / Session-1 / Hall-3

Ankara Local Time: 10:30-12:30

Sivas University of Science and Technology

HEAD OF SESSION: Prof. Dr. Sabit HOROZ

Authors	Affiliation	Presentation title
Engin ESER Bahar Kuloğlu Engin ÖZKAN	Erzincan Binali Yıldırım University	Mersenne Quaternions and Their Basic Properties
Şevval ANCIN Gülay DEMİR Hanım Eda GÖKTAŞ	Sivas Cumhuriyet Üniversitesi	Bibiometric Analysis of the Effect of Spaceflight Exposure on Astronauts in Space Medicine
İsmail ALTUNTAŞ Ferhan Kübra ÖZBAKIR	Sivas Cumhuriyet University	Optimization of V/Iii Ratio in Aln Thin Films on Patterned Sapphire Substrates
İsmail ALTUNTAŞ Ferhan Kübra ÖZBAKIR	Sivas Cumhuriyet University	Temperature Optimization of Aln Thin Films on Patterned Sapphire Substrate
Arda Ahmet ATEŞ Hasan Onur ATAÇ Mehmet GÜÇYETMEZ	Sivas University of Science and Technology	Evaluating Pmsm Motor Technology Within Sustainable Transportation Frameworks: A Case for Electric Vehicles
Hasan Onur ATAÇ Arda Ahmet ATEŞ Mehmet GÜÇYETMEZ	Sivas University of Science and Technology	Machine Learning-Based Estimation of Active Power in Wind Energy Systems
Rıdvan POLAT Oğuz KAYNAR Rukiye KARAKIŞ	Sivas Cumhuriyet University	A Deep Learning Approach for Distinguishing Real and Synthetic Voices Using Mel-Spectrograms
Kali GÜRKAHRAMAN Rukiye KARAKIŞ	Sivas Cumhuriyet University	Comparative Analysis of Pooling Methods for Feature Aggregation in Alzheimer's Disease Classification Using Deep Learning
İpek BALNAN Sabit HOROZ	Sivas University of Science and Technology	Investigation of Structural and Optical Properties of Cobalt and Iron Doped ZnO Nanoparticles: Potential for Solar Cell Applications
İpek BALNAN Sabit HOROZ	Sivas University of Science and Technology	Enhancement Of Visible-Light-Driven Photocatalytic Activity In Gd-Doped Cdzns Nanocomposites

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30.05.2025/ Session-2 / Hall-1

Ankara Local Time: 13:30-15:30

Sivas University of Science and Technology

HEAD OF SESSION: Prof. Dr. Ömer SÖZEN

Authors	Affiliation	Presentation title
Memduha ERGÜT	Sivas University of Science and Technology	Synthesis and Characterization of Pomegranate Peel Derived Super Activated Carbon: Target Zero Waste
Hilal Burcu ERDEM Muhammad ASIM Memduha ERGÜT	Sivas University of Science and Technology	Phytoremediation of Textile Dye Effluents Using Aquatic Plants
Ömer SÖZEN Tolga KARAKÖY	Sivas University of Science and Technology	A Study on Determination of Yield Characteristics of Some Dry Bean Genotypes
Tolga KARAKÖY Ömer SÖZEN	Sivas University of Science and Technology	Determination of Quality Characteristics of Some Dry Bean Genotypes
Sema TETİKER	Batman University	Rare Earth Elements: Industrial Uses and Reserves
Saliha MOROĞLU Gamze YAYLA ESKİCİ	Sivas Cumhuriyet University	Exploring of the Cognitive Structures of Students of the Faculty of Science, Department of Biology About Clean Water and Sanitation
Duygu Sena YAŞAR Gamze YAYLA ESKİCİ	Sivas Cumhuriyet University	Examination of Science Faculty Students' Opinions on Their Professional Preferences and Reasons
Ahmet YENİKALAYCI Metin YAMAÇ	Muş Alparslan University	Wild Plants Consumed as Food in Muş Province and Their Uses
Mahmut Sami ÖZDEMİR Yaşar TOTİK Gökhan GÜLTEN Süleyman ŞÜKÜROĞLU Emine ŞÜKÜROĞLU İhsan EFEOĞLU	Atatürk University	Improvement of Surface Properties of Az31 Magnesium Alloy Coated by Micro-Arc Oxidation

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30.05.2025 / Session-2 / Hall-2

Ankara Local Time: 13:30-15:30

Sivas University of Science and Technology

HEAD OF SESSION: Assoc. Prof. Dr. Ali Suat YILDIZ

Authors	Affiliation	Presentation title
Ekrem ERÖZ	Sivas University of Science and Technology	Innovation in curriculum and instruction
Mehmet Nurullah ÖNEL Afroz JAVED Yunus ÇELİK	Sivas University of Science and Technology	Design of a Cavitating Injector for Aerospace Engines and Performance Analysis in a Microjet Combustion Chamber
Burhan Necati KIZILOĞLU Yunus ÇELİK	Sivas University of Science and Technology	Enhancing the Aerodynamic Performance of Thick Airfoils Via Flexible Membrane and Gurney Flap Applications
Mustafa Ali AKDUMAN Muhammet SARIKAYA Afroz JAVED Human AMIRI	Sivas University of Science and Technology	Computational Analysis of a Ramjet Engine Intake
Mustafa Ali AKDUMAN Muhammet SARIKAYA Afroz JAVED Human AMIRI	Sivas University of Science and Technology	Investigation of Local Pressure Gradients on the Flame Holder of a Fighter Jet Engine
Levent GÖKREM Abdulsamet YURTSEVEN	Tokat Gaziosmanpaşa University	Theoretical Analysis of the Transfer Function of a Finfet (Fin Field Effect Transistor) under Three-Tone Excitation
Levent GÖKREM Melike İMRE	Tokat Gaziosmanpaşa University	Scattering Parameter Analysis of (Fin Field Effect Transistor) Finfet
Sefa Burhan EKER Ali Suat YILDIZ Selim SIVRIOGLU	Sivas University of Science and Technology	Trajectory Tracking Performance of Backstepping and Lqr Controllers on a Ball and Plate Setup

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30.05.2025 / Session-2 / Hall-3

Ankara Local Time: 13:30-15:30

Sivas University of Science and Technology

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Authors	Affiliation	Presentation title
Neslihan DİKBAŞ Şeyma ALIM Sevda UÇAR Ahmet TÜLEK Ayşegül DİKBAŞ	Atatürk University	Partial Purification and Biochemical Characterisation of Phytase from *Bacillus subtilis* ND44 Isolated from Field Soil
Dilruba BAYRAV Hasan YILMAZ	Atatürk University	Alternative Landscape Designs to Reduce Urban Heat Island Formation; the Example of Sïvas City Square
Hale GÜNAÇTI Seral YÜCEL Muhammed TATAR	Sivas Science and Technology University	Effects of Solarization and Fumigant Applications on Wilt and Root Rot Disease in Tomato
Sedat SEVEROĞLU Burak KARACA	Atatürk University	Land Degradation in Rangelands: Causes, Indicators, and Management Strategies
HALİT AKTAŞ SEDAT SEVEROĞLU	Atatürk University	Grassland Biodiversity: Current Status and Challenges
Salma Naimatullah SOOMRO Sabeen Rehman SOOMRO Muhammad AASIM	Sivas University of Science and Technology	Growth of Cotton Cultivars in Response to Multiwalled Carbon Nanotubes
Sabeen Rehman SOOMRO Salma Naimatullah SOOMRO Muhammad AASIM	Sivas University of Science and Technology	Validation and Prediction of *in Vitro* Germination and Growth of Cowpea (*Vigna unguiculata* L.) Cultivars.
Kenan KARA İrfan ÇORUH	Atatürk University	Investigation of the Effects of some Herbicides Treatments on Yield against Common Weeds in Sugar Beet Planting Areas of Bayburt Province

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 / Session-3 / Hall-1

Ankara Local Time: 15:30-17:30

Sivas University of Science and Technology

HEAD OF SESSION: Assoc. Prof. Dr. Emre EVLİCE

Authors	Affiliation	Presentation title
Burhan TOKGÖZ Zeynep YUMLU Emre EVLİCE	Sivas University of Science and Technology	Plant Protection Problems and the Status of Chemical Control in Potato in Turkey
Osman ÇETİN Zeynep YUMLU Mustafa ALKAN Emre EVLİCE	Sivas University of Science and Technology	Bibliometric Analysis of Scientific Publications on the Use of Mentha and Lavandula Essential Oils against some Storage Pests
Yusuf AKGÜL Şerife DÜZEN Ayselnur ŞAHİN Ecem KARA Hatıra TAŞKIN Gökhan BAKTEMUR Asuman KAPLAN EVLİCE	Sivas University of Science and Technology	Evaluation of Drought Stress in Plant Melissa (*Melissa officinalis* L.) under *in Vitro* Conditions
Ecem KARA Hatıra TAŞKIN Gökhan BAKTEMUR	Sivas University of Science and Technology	Effects of Increasing Salt Concentrations on the Morphological Development of Broccoli under *in Vitro* Conditions
Büşra ERGÜL Ayselnur ŞAHİN Şerife DÜZEN Miraç ŞAHİN Ecem KARA Hatıra TAŞKIN Gökhan BAKTEMUR	Sivas University of Science and Technology	Determination of Drought Stress in Summer Squash Varieties under *in Vitro* Conditions
Ecem KARA Hatıra TAŞKIN Gökhan BAKTEMUR	Sivas University of Science and Technology	Investigation of *in Vitro* Responses of Parsley to Salt Stress
Gökçe ÖZDEMİR	Sivas Cumhuriyet University	Precision Livestock Farming: Potential and Risks of Using Digital Technology in Animal Husbandry
Ramazan KATIRCI Hilal ÇELİK	Sivas Cumhuriyet University	Learning Rate Sensitivity in Transformer Models: A Case Study in Neural Machine Translation

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30.05.2025 / Session-3 / Hall-2

Ankara Local Time: 15:30-17:30

Sivas University of Science and Technology

HEAD OF SESSION: Prof. Dr. Sabit HOROZ

Authors	Affiliation	Presentation title
Kağan Murat PÜRLÜ Kübra KÖŞE KAYA Sabit HOROZ Kholoud ELMABRUK	Sivas University of Science and Technology	Dielectric Properties of Cadmium Sulfide in the Terahertz Frequency Band
Kağan Murat PÜRLÜ Şekip DALGAÇ Kholoud ELMABRUK	Sivas University of Science and Technology	Design and Characterization of Antiresonant Negative Curvature Waveguides for Terahertz Applications
İsmail TUNÇİL Mustafa Ali AKDUMAN Afroz JAVED	Sivas University of Science and Technology	A Study on The Effect of Input Power on Resistojet Performance
Şeyda ÖZTÜRK KİRİŞLİ Afroz JAVED	Sivas University of Science and Technology	Turbulence and Viscous Effects in Small Solid Rocket Motors
Kağan Murat PÜRLÜ Elif IŞIK Betül KAFKASLIOĞLU YILDIZ Kholoud ELMABRUK	Sivas University of Science and Technology	Impact of Zro_2 and Ni Additives on The Properties of Al_2O_3 -Based Ceramics in the Terahertz Band
Şekip DALGAÇ Kağan Murat PÜRLÜ Kholoud ELMABRUK	Sivas University of Science and Technology	Signal to Noise Ratio Analysis of Hermite Cosine-Hyperbolic Vortex Gaussian Beams in Turbulent Free-Space Optical Communication Links
Şakir HACIALİOĞLU Kutay ÇAVA Oğuzhan BAŞER Hüseyin İPEK Ahmet KÜÇÜK Altuğ UŞUN Mehtap Pehlivanlar KÜÇÜK Mustafa ASLAN	Karadeniz Technical University	Design and Production of a Reusable Ergonomic Video Laryngoscop
Şakir HACIALİOĞLU Mustafa ASLAN Özge Nur ERDEYER Ali TEMİZ Gökhan HEKİMOĞLU İbrahim ALPAK	Karadeniz Technical University	Balsa Core Composite Sandwich Panel Containing Peg 400

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 / Session-3 / Hall-3

Ankara Local Time: 15:30-17:30

Sivas University of Science and Technology

HEAD OF SESSION: Assoc. Prof. Dr. Nazım BABACAN

Authors	Affiliation	Presentation title
Neslihan DERELİ	Sivas Chamber of Certified Public Accountants	Neuroscientific Foundations of Financial Decision-Making: A Neuroaccounting Approach
Neslihan DERELİ	Sivas Chamber of Certified Public Accountants	An Empirical Study on the Reliability of the Beneish M-Score Model: Analysis of Fraudulent Financial Reports
Halime SUVAY EKER	Istanbul Gedik University	Examination of Internet Usage Purposes in Türkiye on the Variables of Year and Gender
Ahmet Turan İNCE İsakhan KARABAŞ Rahimullah MURADI	Erzincan Binali Yıldırım University	A Pilot Study on the Feasibility of Using Chatbots in Medical Education Through Committee Questions
İsakhan KARABAŞ Fulya ASLAY	Erzincan Binali Yıldırım University	Biometric Analysis on The Use of Artificial Intelligence in Space Science
Fatma BAYDAR Halit BAKIR Metin ZONTUL	Sivas University of Science and Technology	Intrusion Detection for Iot Devices Using Federated Learning
Muhammed Taha YILDIZ Rumeysa ÖZDEMİR Nazım BABACAN Akın ORHANGÜL	Sivas University of Science and Technology	Investigation of Beam Compensationon Dimensional Accuracy of a Lpbf-Manufactured Co–Cr Alloy Jet Engine Component
Muhammed Furkan ŞAHİN Muhammed Taha YILDIZ Zeynep AKÇAKAYA Emre YURTKURAN Nazım BABACAN	Sivas University of Science and Technology	Investigation Of Process Parameters On Density Of Lpbf-Manufactured Co-Cr Alloy Samples
Gamze SAATÇI Sevda KORKUT	Erciyes University	History of Evidence-Based Nursing Practice
Gamze SAATÇI Sevda KORKUT	Erciyes University	Health Behavior Change in Nursing Practice: Transtheoretic Model Approach

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30.05.2025 / Session-3 / Hall-4

Ankara Local Time: 15:30-17:30

Sivas University of Science and Technology

HEAD OF SESSION: Res. Assist. Muhammed TATAR

Authors	Affiliation	Presentation title
Oktay ÖZBAY Elif TOZLU	Atatürk University	Detection of Fungal Diseases in Sugar Beet Cultivation Areas in Bayburt Province
Kağan KÖKTEN Hale GÜNAÇTI Muhammed TATAR Meliha Feryal SARIKAYA Amjad ALİ	Sivas University of Science and Technology	Next-Generation Molecular Diagnostics for Plant Pathogen Detection: Innovations, Applications, and Future Perspectives
Muhammed TATAR Fatih ÖLMEZ Fatih DADAŞOĞLU	Sivas University of Science and Technology	Harnessing the Power of Soil Microbes: A Mini-Review on Their Role in Plant Growth Promotion and Health
Muhammed TATAR Amjad ALİ Sezai ERCİŞLİ	Sivas University of Science and Technology	Harnessing Molecular Markers to Unravel Pathogenic Diversity: Implications for Plant Disease Management

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 | SESSION-1 | HALL-1

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Gökhan BAKTEMUR

Authors	Affiliation	Presentation title
Emir DEĞİRMENCİ Ali Barış HAZİNEDAR Yunus Emre KARASU	Karabük University	Intelligent Agriculture Monitoring and Automation System
Veysel ALP	Harran University	Assessment of Soil Quality with the Smaf Method
Kübra KELEŞ Nurhan KOÇAN	Bartın University	Recrational Landscape Design Project Of Bartin River Kanliirmak Location
Canan TANŞU Nurhan KOÇAN	Bartın University	Landscape Design Project Of Küçükçekmece Balikçi Island Park
Berrin Nagehan BAYAR Nurhan USLU Mehmet Musa ÖZCAN	Selçuk University	Effect of Different Salt Usage on Bioactive and Sensory Properties of Table Olives
Sebiha EROL UYANIK Emine BUDAKLI ÇARPICI	Bursa Uludag University	The Effects of Increasing Nitrogen Doses on the Silage Quality of Bagasse in some Sweet Sorghum Cultivars Grown under Second Crop Conditions
Sebiha EROL UYANIK Emine BUDAKLI ÇARPICI	Bursa Uludag University	Effects of Different Nitrogen Fertilization on Silage Quality of some Sweet Sorghum Cultivars Grown under Second Crop Conditions
Tuğba KARABOĞA Hasan Aykut KARABOĞA	Amasya University	New Trend in Application Development: Benefits and Challenges of Low-Code/No-Code Platforms for Organizations

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30.05.2025 | SESSION-1 | HALL-2

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Fikret SAYGIN

Authors	Affiliation	Presentation title
Alper Veli ÇAM Büşra GARİP Nisanur YILMAZ KAZANCI	Gumushane University	Examining the Impact of Artificial Intelligence on the Labour Market
Halil KAYNARPINAR Abdulkadir ŞEKER	Sivas Cumhuriyet University	Evaluating the Effectiveness of Generative Ai Models in Solving Fundamental Algorithmic Challenges
Uğur SÖZLÜ	Tokat Gaziosmanpaşa University	Analysis of Exercise Videos Through Ai-Assisted Visual Assessment: A Comparison between Chatgpt 4.5 and Physiotherapist Evaluations
Ramazan KATIRCI Taha OĞUZ	Sivas University of Science and Technology	The Effect of the Use of Complexifiers on Chemical Composition in Cr-Ni Coatings
Esma HARMANCI Halil ARSLAN	Sivas Cumhuriyet University	Comparison of Vulnerability Scoring Systems: The Cvss and Epss
Yeşim ÇAĞIL Mehmet MİMAN	Harran University	Servqual Method in Measuring Service Quality and Related Literature Review
Görkem Enes İNCİ Murathan AKTAŞ Mehmet MİLLİ	Bolu Abant İzzet Baysal University	Intelligent Optimization of Airline Ticket Prices Via a Genetic Algorithm-Based Dynamic Approach
Tayfun TURAL Yunis TORUN	Sivas Cumhuriyet University	Deep Learning-Based Power Outage Prediction Using Meteorological and Grid Data
Murat TOPALOĞLU	Tokat Gaziosmanpaşa University	Artificial Intelligence and Employee Engagement: Opportunities and Challenges in Hrm

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30.05.2025 | SESSION-1 | HALL-3

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Melih OKCU

Authors	Affiliation	Presentation title
Renim HUSSIN Beyda ALAGÖZ Serap YÜCEL Fatma KAYKI Furkan DİNÇER Yavuz CANBAY	Kahramanmaraş Sütçü Imam University	A Web-Based Machine Learning Application for Solar Power Generation Prediction
Renim HUSSIN Beyda ALAGÖZ Serap YÜCEL Fatma KAYKI Furkan DİNÇER Yavuz CANBAY	Kahramanmaraş Sütçü Imam University	Detection of Ramp-Down Events in Solar Power Generation Data
Hakan TOPAL Fatih Vehbi ÇELEBİ	Ankara Yıldırım Beyazit University	Target Detection by Synchronizing Small Unmanned Aerial Vehicles (Uavs) and Face Recognition System
Neşe AYKUT	Ağrı İbrahim Çeçen University,	Parkinson's Disease and Nursing Management
Ahmad A. BELLO Toyese OYEGOKE	Ahmadu Bello University	Thermodynamic Feasibility of Ammonia Valorization for Clean Energy and Environmental Applications
Ahmet Serdar YILMAZ Özgür CENGİZ Furkan DİNÇER	Kahramanmaraş Sütçü İmam University	Digital Twin Based Distribution Network Management: Integration of GIS, SCADA and AMR
Ahmet Serdar YILMAZ Özgür CENGİZ Furkan DİNÇER	Kahramanmaraş Sütçü İmam University	Digital Twin Application for Real-Time Monitoring and Optimization of Electricity Distribution Infrastructures
Asude HANEDAR Busra AVCI Aysegul TANIK	Tekirdag Namik Kemal University	Ghg Emission Calculations and Reduction Suggestions in an Sme-Sized Secondary Aluminum Foundry

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30.05.2025 | SESSION-1 | HALL-4

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Subhashish DEY

Authors	Affiliation	Presentation title
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	The Role of Lifestyle Factors in Male Fertility: A Review of Exercise, Smoking, and Alcohol Consumption
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Trends in Global Decline of Sperm Quality: A Meta-Analysis
E. ELAVARASI Yuvaraj AR J. JAYADURKA R. SRINIVASAN	Bharath Institute of Higher Education and Research Chennai-73	Artificial Intelligence in Drug Discovery in Medicinal System
Joseph Chisom OKOYE	NIGERIAN YOUNGRESEARCHERS ACADEMY	Assessing the Potential of Various Medicinal Plants as Alternatives to the Lasota Vaccine Used in Poultry Production for Newcastle Disease Prevention: A Review
V. VIJITHA S. MADHUMITHA Dr. K. RAJAGANAPATHY	Bharath Institute of Higher Education and Research	Review on Oral Drug Delivery System
Asel PAZYLOVA	Osh Technological University	Investing in Sustainable Development of Regions of Kyrgyzstan
Subhashish DEY	Gudlavalleru Engineering College, Andhra Pradesh	Seismic Analysis of Comparitive Multi - Storey Building
Subhashish DEY	Gudlavalleru Engineering College, Andhra Pradesh	Application of Industrial Waste Materials for the Preparation of Green Bricks
Chayaraju Bala Sai Nadagouda Kalyani K. Tharani	G.pullareddy Engineering college	Analysis Of Geopolymer Concrete's Compressive Strength Parametrically
R.P. Meenaakshi Sundhari Mr.G.Aravind Mr.S.Sriharish Mr.K.Vasanthakumar Mr.D.Umashankar	P.A. College of Engineering and Technology	Smart Helmet With Effective Alcoholic Detection System And Emergency Sos
Yerida Yenti	Universitas Metamedia	The Influence Of Gender On University Students' Academic Spending In The Digital Era: A Case Study Of Students In Padang
Felicia KING-AGBOTO Chizoma Catherine OKPARA	Captain Elechi-Amadi Polytechnic	Effects Of Brain Focus Learning Strategies For Improving High Performance Among Secondary Schools Students In Rivers State,Nigeria
Afaq AHMAD Basant KUMAR Rajeev RAJENDRAN Mohamed SIRAJUDEEN YOOSUF	Modern College of Business and Science	On Semiconductor Industry And Its Growth
Krisdela Kaçani Myriam González-Limón Luis Miguel López – Bonilla Elena Kokthi	University of Seville	Green Banking: Drivers And Barriers

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30.05.2025 | SESSION-1 | HALL-5

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Melik SAMI

Authors	Affiliation	Presentation title
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	From Pantry to Biolab: Reimagining Kitchen Typologies for Future Food Innovation
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Waste Not: Integrating Composting and Resource Recovery in Smart Kitchen Architecture
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	IoT and AI in the Kitchen: Architectural Implications of Connected Food Systems
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Designing Kitchens for Nutritional Wellness: A Behavioral Architecture Approach
Hajar LOUHAB Colette BESOMBES Raowia LAMHAR Adil DANI Hamid MELLOUK Karim ALLAF Khalid DIGUA Bouchra BEJJANY	Hassan II University	Improving the Recovery of Bioactive Molecules from Coffee Waste through Innovative Thermo-Mechanical and Microwave-Assisted Methods
Rabia CHOUDHARY Wafa MAJEED AYESHA Bilal ASLAM Muhammad Saad TARIQ	University of Agriculture	Antidiabetic Activity of *Grewia asiatica* Seed Extract in Streptozotocin Induced Diabetic Rats
Haseeba FARRUKH Wafa MAJEED AYESHA Muhammad Saad TARIQ	University of Agriculture	Cordia Sinesisameliorates Diabetes Associated Dyslipidemia in Stz Induced Diabetic Rats
Bahareh RAFIEI Mohbobeh SHARIFI	Plant Protection Research Department, Gilan Agricultural and Natural Resources Research and Education Center	Survey of Parasitoids Associated with White Peach Scale (*Pseudaulacaspis pentagona*) in Kiwi Orchards of Gilan Province, Iran
Carla Santos	New University of Lisbon	Representation Systems And The Mitigation Of Probabilistic Fallacies
Faisal Hussein Mohammed Waheeb	Pioneers Education, Social Sciences	The Role Of Tourism Marketing In Optimizing City Tourism In Jordan-South Levant - Amman Case Study
Aswin M Nair Payal Shukla Bhumika Sharma3	Sharda University	A Study Of Various Neglected Agents Of The Greenhouse Effect:Moss As A Co2 Absorbent
Bushra Ansari Mahendran Sekar	Monash University	Metabolic Profiling Of Gut-Brain Axis: A Strategy To Decipher Metabolites Affecting Alzheimer's Diseases (Ad) Diseases By Using Metabolomics

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30.05.2025 | SESSION-1 | HALL-6

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Afroz JAVED

Authors	Affiliation	Presentation title
Abdullahi UMAR Mogaji Umar MUHAMMED Toyese OYEGOKE	Ahmadu Bello University	A Molecular Modeling Approach to Sustainable Drug Delivery: Improving Ibuprofen Solubility Through Deep Eutectic Solvents
S. JAYASHREE V. RAKSHANA R. SRINIVASAN	Bharath Institute of Higher Education and Research	Fighting Diabetes with Herbal Technology
V. RAKSHANA K. DIVYA	Bharath Institute of Higher Education and Research	Pharmacy Services for Patients with Allergies
V. SARASWATHI W. HELEN	Bharath Institute of Higher Education and Research	A Comprehensive Review on Nutraceuticals: Therapy Support and Formulation Challenges
K. RAJAGANAPATHY MADHUMITHA.S, VIJITHA, V	Bharath Institute of Higher Education and Research	Meningitis: Inflammation of the Brain and Spinal Cord Membranes
N. JAYARAMAKANI M. KOWSIKA	Bharath Institute of Higher Education and Research	Rabies Disease
E. ELAVARASI Yuvaraj AR J. JAYADURKA R. S. DEEKSHITH R. SRINIVASAN	Bharath Institute of Higher Education and Research	Metformin: A Biguanide for Type 2 Diabetes Management
Sakineh Khanamani FALAHATIPOUR Sara Shokrpoor MINA Khodadadi Fatemeh MOHITI	University of Tehran	Evaluating the Metabolic Effects of *Garcinia cambogia* Supplementation in Streptozotocin-Nicotinamide-Induced Type 2 Diabetic Rats

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30.05.2025 | SESSION-2 | HALL-1

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Asuman KAPLAN EVLİCE

Authors	Affiliation	Presentation title
Erhan BAYSAL Fulya KAHRIMAN Oğuz KOÇAR	Zonguldak Bülent Ecevit University	Effects of Rare-Earth Element Gd Addition on Microstructure and Mechanical Properties of 8090 Al-Li Alloy
Omar HATHAT Şakir ŞAHİN	Süleyman Demirel Üniversitesi,	Improving Solar Panel Performance: Environmental Compatibility of Nano Coatings
Fuat KARTAL Arslan KAPTAN	Kastamonu University	Optimization of Printing Parameters in 3d Fdm Printers: An Experimental Approach Based on Performance and Quality Criteria
Alperen DEVELİ Yusuf FEDAİ Emre ÖZER Gökhan BAŞAR Oğuzhan DER	Osmaniye Korkut Ata University	Influence of Mwcnt-Enhanced Minimum Quantity Lubrication on Power Consumption and Surface Roughness in Face Milling of Aisi 304 Stainless Steel
Burcu AYDIN Belgin GÖZMEN SÖNMEZ Özkan GÖRMEZ	Mersin University	Investigation of the Effect of Molybdenum Sulfide on the Degradation of Vanillin by Electro-Fenton Method
Şeyma AKTAŞ Yılmaz MERT Salih ÖZBAY	Sivas University of Science and Technology	The Effects of Molecular Weight and Coating Conditions on the Surface Wettability of Pmma Films
Ömer KORKMAZGÖZ Cevdet SÖĞÜTLÜ	Gazi University	Determination of abrasion and scratch resistance of pvc, pet and pmma
Melike Hilal DİNGİLOĞLU Vedat ÖZYAZGAN	Haliç University	The Use of Clay as a Sustainable Dyestuff in Textiles

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30.05.2025 | SESSION-2 | HALL-2

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Hale GÜNAÇTI

Authors	Affiliation	Presentation title
Şakir ŞAHİN	Süleyman Demirel Üniversitesi,	Occupational Safety in Oral and Dental Hospitals
Ekrem AKBULUT Mehmet Emin ALHAN	Malatya Turgut Ozal University	Effects of Helicase Protein Mutations in American Isolates of SARS-Cov-2
Ekrem AKBULUT Meltem YILDIRIM Hüseyin KAHRAMAN	Malatya Turgut Ozal University	Changes in the Spike Protein of the SARS-Cov-2 XBB.1.5 Variant
Hamza ÖZEL Barış Atalay USLU Menekşe TAŞ DİVRİK	Sivas Cumhuriyet University	Different Progesterone-Supported Estrus Synchronisation Protocols in Heifers
Fatma BULUT Esra Bulut ATALAY Taner DAŞTAN	Sivas Cumhuriyet University	Investigation of the Anticarcinoserogen Activity of Chestnut (*Aesculus hippocastanum* L.) Plant against Breast Cancer Cells
Aslıhan SÖNMEZ Volkan ATES	Tarsus University	Spiking Neural Networks for Early Skin Cancer Detection: A Delta-Modulation-Based Approach on Ham10000
Zeynep AVCI Figen ÇALIŞKAN	Trakya University	Examination of Nurses' Self-Directed Learning Skills
Meltem KAYA Birgül CERİT	Karabük University	Determination of Nursing Students' Technostress Levels in a Technology-Supported Learning Environment

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30.05.2025 | SESSION-2 | HALL-3

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Halit BAKIR

Authors	Affiliation	Presentation title
Hicret HOPOĞLU Ebru Şenadım TÜZEMEN	Sivas Cumhuriyet University	Development of Ga_2O_3 Films Grown on Sapphire by Rf Magnetron Sputtering Method at Different Powers for Uv Photodetector Applications
Burak İRI	Yıldız Technical University	Cost-Benefit Analysis in Smart Transportation System Applications
Burak İRI	Yıldız Technical University	Position Detection and Debugging of Rotor Speed-Position Sensor Connectors in Electric Vehicles with Point-Cloud Technology
Metin DEMİRTAŞ Yasin AYDIN	Balıkesir University	New Approaches to Identity Verification of Cattle in Smart Agriculture Applications
Metin DEMİRTAŞ Yasin AYDIN	Balıkesir University	Electronic Circuit Design for Mastitis Detection
Soukaina El BOURACHDI Abdelhay El AMRI Yassine RAKCHO Amal LAHKIMI	Sidi Mohamed Ben Abdellah University	Upcycling Lithium-Ion Battery Waste into High-Performance Reduced Graphene Oxide via Aloe Vera-Assisted Green Chemistry: Engineering a Chitosan@EDTA@rGO Hybrid for Rhodamine B Adsorption and Theoretical Interaction Profiling through DFT
Jogendra KUMAR	G.B. Pant Institute of Engineering and Technology	Optimizing Resource Allocation in 5G Networks Through Hybrid Machine Learning and Blockchain Technologies
Edionsenyene UDOH	Madonna University	Evaluation of Liver Function Status of Students Predisposed to Obesity in Madonna University, Elele, Nigeria

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30.05.2025 | SESSION-2 | HALL-4

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Nitiksha PARIHAR

Authors	Affiliation	Presentation title
Nitiksha PARIHAR Barinderjit SINGH	I.K. Gujral Punjab Technical University	Antioxidant Potential and Bioactive Profile of Selected Millets: A Nutritional and Functional Food Perspective
Rabar Mohammed HUSSEIN	Noble Technical Institute	Key Factors Influencing Phytoplankton Abundance in Alkaline, Unproductive Lakes
Divya BHARTI Barinderjit SINGH	I.K. Gujral Punjab Technical University	Citrus Pseudolimon Peel Incorporated Muffin: Effect on the Phytochemical and Sensorial Properties of Muffin
Akanksha THAKUR Barinderjit SINGH	I.K. Gujral Punjab Technical University	Muffin Development with Citrus Jambhiri Peel Powder Incorporation
Arshdeep SINGH	I.K. Gujral Punjab Technical University	Optimization of Ultrasound-Assisted Extraction (Uae) of Polyphenols from Browntop Millet Flour Using Response Surface Methodology (Rsm)
Vaishnavi MEHRA	I.K. Gujral Punjab Technical University	Formulation and Functional Evaluation of Spinach-Enriched Gluten-Free Crackers from Buckwheat and Rice Flour Blends
Emmanuel Tomisin BELLO Sunday AWE	Newland Polytechnic and College of Health Technology	Redefining Medical Microbiology: The Emerging Role of Nanobiotechnology
M.S SADIQ I.P SINGH M.M AHMAD B.S SANI	FUD, Dutse, Nigeria	Cold Storage Solutions to Reduce Post-Harvest Loss: Start-ups for Youth in the Agricultural Supply Chain
Maroine FLOUCHI Karim FAHSI Karim CHKIRATE Redouane ACHOUR	Mohammed V University in Rabat	Phytochemical Characterization And Antioxidant, Antimicrobial, And Antidiabetic Activities Of Moroccan Myrtus Communis L. Essential Oil: In Vitro And In Silico Investigations
Zohaib Hassan Sain	Universitas Brawijaya	The Effect Of Gamified Mobile Learning Apps On Enhancing Critical Thinking Skills In Primary School Students For Environmental Education
Aleksandra Ravnachka Velimira Stoyanova Dessislava Poleganova	Bulgarian Academy of Sciences	Understanding Regional Inequality In Bulgaria: A Demographic And Labor Market Perspective
Udoye, Charles Ekene Egbo Angela Nnenna	University of Nigeria	Odour Control Measures Among Poultry Farmers In Enugu East Senatorial Zone, Enugu State, Nigeria
Dorina SAJA	University of Tirana	The Function And Responsibilities Of Judicial Police Officers In The Course Of Preliminary Criminal Investigations
Bahia MESSAI Rachid MAKHLOUFI	University of Biskra	Structural And Electrical Characterization Of Srf_2-Modified Pzt Ceramics Near The Morphotropic Phase Boundary
László Pitlik László Pitlik (Jr.) Mátyás Pitlik	Kodolányi University	Operationalized Measurement Process For Model-Qualityevaluation In Case Of Data Assets Based On Questionnaires
Rozina Khattak	Shaheed Benazir Bhutto Women University	The Hidden Powers Of Tert-Butanol In Catalysis
Rozina Khattak	Shaheed Benazir Bhutto Women University	Transforming Trash Into Treasure For Wastewater Cleanup

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

30.05.2025 | SESSION-2 | HALL-5

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Mahendra Kumar SAVITA

Authors	Affiliation	Presentation title
R. VIDHYALAKSHMI C. REJITHA	Bharath Institute of Higher Education and Research	Neuroinflammation as a Key Mechanism in Neurological Diseases
E. ELAVARASI Yuvaraj AR J. JAYADURKA R. SRINIVASAN	Bharath Institute of Higher Education and Research	Recombinant DNA Technology and Protein Engineering: Powerful Tools for Biological Innovation
K. POOJA M.K. VIJAYALAKSHMI	Bharath Institute of Higher Education and Research	Overview on Urinary Tract Infection
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Advances in Sperm Epigenetics: Implications for Fertility and Offspring Health
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Natural and Clinical Approaches to Boosting Sperm Health
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Targeted Strategies to Improve Sperm Count, Motility, and Morphology
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Effect of Obesity and Metabolic Syndrome on Sperm Parameters in Reproductive-Aged Males
Mahendra Kumar SAVITA	Naraina Vidyapeeth Engineering and Management Institute	Environmental Pollutants and Their Role in Male Infertility: A Focus on Endocrine Disruptors

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 | SESSION-2 | HALL-6

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Amjad ALİ

Authors	Affiliation	Presentation title
Ehab ISMAEL	Baku State University	Strategic Narratives: How Media Influences Foreign Policy Decisions in Global Power Struggles
Ehab ISMAEL	Baku State University,	Social Media's Role in International Crises: A Strategic Tool for Influence, Perception Management, and Crisis Diplomacy (2015-2025)
Julie Anne C. QUIÑONES Baby Boy Benjamin D. NEBRES	Bicol University	Resource Development and Management: Daraga Community College Experience
Zouheir MSATFA	Hassan First University	Foundations and Conceptual Models of Taxpayer Tax Compliance
Manya BISHT Jogendra KUMAR Rishit RAWAT Neha ANGARIA Ravi KUMAR Aanchal SINGH	G. B. Pant Institute of Engineering and Technology	Real-Time Driver Drowsiness Detection Using Eye and Mouth Aspect Ratios for Enhanced Road Safety
Osamah Mohammed JASIM	University of Delhi	Personalized Learning Pathways: Using NLP and Blockchain for Adaptive Curriculum Design and Student Progress Tracking
Gbenga JOHN	Adekunle Ajasin University	Assessment of Factors Influencing Access to Residential Land in Typical Urban Border Communities of Nigeria: A Gender Dimension
Alvan JAFAROV	Azerbaijan State Pedagogical University	New Approaches to Mentor Training at Azerbaijan State Pedagogical University

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 | SESSION-3 | HALL-1

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. İlhan DANACI

Authors	Affiliation	Presentation title
ZEHRANUR AKBULUT Ahmet ŞİRİN	Istanbul University-Cerrahpaşa,	A Career Program to Enhance Career Competence, Career Optimism and Adaptability in the Transition from University to Work
Alper Veli ÇAM Khadıhatou SIDIYA	Gumushane University	Disaster Response and Emergency Medical Services: Challenges and Solutions
Serkan DEMİR Taner AŞÇI	Ankara Yıldırım Beyazıt University	Examining the Ergonomics, Visual and Communication Elements of Kindergarten Classes
Gökhan ACAR Barbaros Serdar ERDOĞAN	Uşak University	The Political Instrumentalization of Sport: Sports Policies in Authoritarian Regimes
Amouna Marwa ABU-DHAIM Onur ER	Düzce University	Problems in Teaching Turkish as a Foreign Language in Jordan
Hafize Nurgul DURMUS SENYAPAR	Gazi University	Energy Justice and the Social Determinants of Health: A Critical Examination of The Impact of Energy Poverty on Social Health
Melike AKMAN Arta JAKUPI Filiz KUMOVA Nevin KILIÇ	Fatih Sultan Mehmet Vakıf University	Evaluation of the Relationships Between Self Differentiation, Parental Attitudes, and Psychological Resilience
Emine Nur YERSEL Ruveyda KARADENIZ Filiz KUMOVA Ayşe Pınar VURAL	Fatih Sultan Mehmet Vakıf University	Evaluation of the Relationship between Body Satisfaction and Social Media Unconsciousness in the Context of Hijab and Potential Protective Factors

(All speakers required to be connected to the session 10 min before the session starts)
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30.05.2025 | SESSION-3 | HALL-2

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. Meliha Feryal SARIKAYA

Authors	Affiliation	Presentation title
Fatih UZUN A. Engin ÖZÇELİK İbrahim DEMİRCİ	Selcuk University	Tests for the Safe Navigation of Electric Vehicles on Highways
Muhammed HASAN Fatih BAYRAK	Siirt University	Impact of Different Ambient Temperatures and Discharge Rates on the Thermal Performance of Lithium-Ion Battery Pack
Murat YAHSI Osman Oguz PELIT Muhammed Furkan YUCE Mustafa BUĞDAY	Karabuk University	Smart Robotic End Effector with Pneumatic Actuation and Human Detection for Industrial Safety
Veysel ALTIN Mustafa BUĞDAY	Karabuk University	Bending Machine Controlled from Mobile Application
Mehmet TOPRAK Murat KAAN Mustafa Serdar GENÇ	Erciyes University	Investigation of Thermal Efficiency in Liquid-Cooled Lithium-Ion Battery Systems
Cerennur ESER Mehmet GÜÇYETMEZ Şekip Esat HAYBER	Sivas University of Science and Tecnology	Use and Benefits of Fiberoptic Vibration Sensors in Battery Management Systems in Military Batteries
Elifnur AYDIN Edanur Dilara MANDACI Ahmet Gürkan YÜKSEK	Sivas Cumhuriyet University,	Comparison of Internet of Things (Iot) Use Cases and Communication Technologies
Caner ÖZDEMİR Nurcihan GÜNSÜR	Mersin University	Design of a Wearable Antenna Integrated onto Military Berets or Kasks for Indoor/Outdoor Positioning Systems

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30.05.2025 | SESSION-3 | HALL-3

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Zemran MUSTAFA

Authors	Affiliation	Presentation title
Verdiyeva Gunay VILAYAT	the Institute of Oriental Studies named after Z.M. Bunyadov of ANAS	A Comparative Analysis of Antonyms in Medical, Technical and Linguistic Terminology in Persian, English and Azerbaijani Languages
Irina-Ana DROBOT	Technical University	The Case of Two Similar Haiku Poems
Adni ISLAMI	University of Pristina	Determination of the Structure and Evaluation of Decorative Trees in Nënë Tereza Square, Prishtina
Bourenine KAHINA Nait Kaci-Boudiaf MALIKA Saadoun NORIA	Mouloud Mammeri University	Grenadine Molasses: Between Promises and Challenges
Diellorita ABAZI	International University of Struga	Digital Transformation and Innovation: The Role of Technology in Shaping Socio- Economic Development
Joy Nneka UCHENYE EJIKEME	University of Nigeria	Women and Food Tourism: Exploring Gender Roles in Culinary Traditions of Southeastern Nigeria
Maja PUCELJ Lea-Marija COLARIČ-JAKŠE	EMUNI University	Women in Rural Slovenia Navigating the Triple Burden of Labour, Agriculture and Household Care
Irakli BASHELEISHVILI Elza BITSADZE Nodar CHANTURIA Givi LOBZHANIDZE Tsatsa NAMCHEVADZE Nana Oniani-SAGHINADZE	Akaki Tsereteli State University	An Intelligent System for the Evaluation of Scientific Papers Based on Fuzzy Logic

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30.05.2025 | SESSION-3 | HALL-4

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Weam Saad Al-HAMADANY

Authors	Affiliation	Presentation title
Julius Oluwayomi OLUWADAMILARE Bashiru Adeniyi ADEGBITE Akinyele John AJIBOYE Abiodun David AROWOLO	University of Ilesa	Ethnomusicological Perspective of Ebenezer Obey's Song Operation Feed the Nation on Food Sovereignty in South West Nigeria
Neha	Swami Vivekanand Subharti University	The Mechanism between the Optimization of Rural Educational Resources and Regional Agricultural Economic
Zahra BELLIL Assia MAIRI Dassine BELLIL Sylvain MEYER Valentin TILLOY Christophe De CHAMPS Olivier BARRAUD Abdelaziz TOUATI	Université de Bejaia	Whole Genome Sequencing of *Nontyphoidal salmonella* isolated from Food- Animal Products in Bejaia, Algeria
Chaima MOUFFOUK Soumia MOUFFOUK Hamada HABA Abdelbasset TAMERSIT	University of Batna 1	Bioactive Molecules from Scabiosa Stellata as Powerful Inhibitors of Cyclooxygenases 1 and 2, 5- Lipoxygenase, and Nf-Kb Protein: *in Vivo*, Molecular Docking, and in Silico Approaches
Mohamed EL AMMARI Kaoutar FAHAD Fatima EL BAHJA Hassan BOUKITA Imane MRABTI Najiba BRHADDA Said BOUZAKRAOUI Rabea ZIRI	Ibn Tofail University	A Systematic Literature Review on the Phytochemical and Insecticidal Properties of Plant Oils and Extracts against *Ceratitis capitata*
Kaouthar ELBIRGUI Houssam ASSIOUI Oussama RAFIK Nadia IOUNES Samir IBENMOUSSA	University Hassan II	Comprehensive Phytochemical Profiling Via HPLC-MS/MS and Bioactivity Assessment of *Ebenus pinnata*: A promising Medicinal Plant Resource
Weam Saad Al-HAMADANY	Ibn Sina University	Fungal Contamination Upon Academic Laboratory, A Biosafety View
Mahdi Tajalian MOFRAD	University of Tehran	Electricity Production from Plants (*Aloe vera*)

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30.05.2025 | SESSION-3 | HALL-5

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Nurbanu GÜZEY

Authors	Affiliation	Presentation title
Bouchra AYAT Maryam HANIF Laila OUARDI Abdellatif BENBOUAZZA Lahcen HSSAINI Rachid RAZOUK Hamid MAZOUZ	Moulay Ismail University	Assessing Effect of Agroecology on Soil Organic Matter and the Agro-Physiological Characteristics of Apple Tree
Arooba SHAHNAZ Muhammad FAISAL	MNS-University of Agriculture	Role of GhFBN in Drought Tolerance in Cotton
Tope James OGIDI	Newland Polytechnic	Biofilm Formation Involving Food Borne Pathogenic and Health Promoting Microorganisms
Ebrahim Mohammed AHMED Gurudutta P. JAPEE Mesud Mohammed AKMEL	Gujarat University	Systematic Literature Review on Adoption of Digital Technologies in Agricultural Accounting and Audit
Otele AMA	School of Applied Sciences, of Science Laboratory Technology, School	Soil Pollutants and Impact on Agricultural Crops
Muhammad SARWAR Muhammad Farrukh SALEEM Basharat ALI Hassaan AHMAD Muhammad SHAHID Abdul SHAKOOR Amina RASHID	University of Agriculture	Role of Potassium, Zinc, and Boron Applications in Modulating Cotton Phenology Under Variable Environmental Conditions
Temitope M. OGUNNIRAN Obianuju N. OKOROAFOR Adaeze B. OBODO	University of Nigeria	The Knowledge, Attitudes, and Practices (Kap) of Poultry Farmers towards the Use of Common Disinfectants in Nsukka L.G.A Of Enugu State
O.A. ADEPOJU T. AGUDE	Federal College of Agriculture Ibadan	Credit Accessibility among Maize Farmers in Ido Local Government Area of Oyo State, Nigeria

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30.05.2025 | SESSION-3 | HALL-6

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Rezan BAKIR

Authors	Affiliation	Presentation title
Tannu GOSWAMI Pratibha SINGH	Manav Rachna International Institute of Research and Studies	Iron Enriched Jam Using Natural Sweetener: A Sustainable Food Approach
Mushfiquer Rahaman RAIHAN	Bangladesh Agricultural University	Interrelation among Halal Meat, Meat Products and Tourism Sector in Asian Continent
P. SARANYA R. VIDHYALAKSHMI G. PRATHEEBA Danish KHAN C. REJITHA	Bharath Institute of Higher Education and Research	Gas chromatography in food analysis
Bharti VASHISTH Pratibha SINGH	Manav Rachna International Institute of Research and Studies	Parenting Style and Nutrition: A Cross-Cultural Synthesis of Evidence on Feeding Practices and Dietary Outcomes
Zineb El HAMRI M. KARAOUI M. ALAMI M. ASSOUAG	University Moulay Ismail	The Impact of NaOH Pretreatment, Thermal Pretreatment, and their Combination (NaOH-thermal) on Biomethane Yield during the Anaerobic Digestion of Walnut Shells
A.M. SANI M.M SHAMSUDDEEN	Kebbi State University of Science and Technology Aliero	Antibiotic Susceptibility Pattern of Bacteria Associated with Hawked Suya-Meat in *Aliero metropolis*
Anam HAMEED Muhammad FAISAL	MNS-University of Agriculture	Mitigation of Salinity Induced Negative Effects on the Germination and Growth of Soybean by Calcium Application
Lamia BERKANE Ghania AHMED Mohammed Sadok DERKI Manel AZZI Chikha MARIA	University of El Oued	Hematological and Biochemical Alterations Induced by Deltamethrin Exposure in Male

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31.05.2025 | SESSION-1 | HALL-1

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Sedat SEVEROĞLU

Authors	Affiliation	Presentation title
Fatma ŞAHIN Nargis ÖZGEN	Hacı Bayram Veli University	The Influence of Social Media Influencers on Generation Z: An Examination of Purchasing Behaviors and Digital Opinion Leadership
Feyzanur GÜN	Düzce University	A Qualitative Analysis of Secondary School Students' Perceptions and Reflections on Their Reading Experiences
Sadhana K Samreen F Thejaswinie A.P Priyadharshini S	R.M.K. Engineering College	Li-Fi Based Indoor Navigation System
Devran Hakan	Ankara Hacı Bayram Veli University	Representations of Kurdish Women in Traditional Media: The Case of Trt Kurdi and Yerevan Radio
Barış KAYA	Ankara Yıldırım Beyazıt University	Otoman Politics and Military Developments from Sultan Osman Iii to Sultan Selim Iii: An Evaluation from the Perspective of the 18th Century
Sagaya Aurelia	CHRIST University	The Comprehensive Horizon of Artificial Intelligence in Veterinary Medicine
Alparslan ERZURUMLU Muhammed Selahaddin ELÇİ Ahmet Serdar YILMAZ	Kahramanmaras Sütcü Imam University	Flyback Circuits Development Board Design in Laboratory Training
Alparslan ERZURUMLU Ahmet Serdar YILMAZ	Kahramanmaras Sütcü Imam University	Sepic Converter Circuits Development Board Design in Laboratory Training

(All speakers required to be connected to the session 10 min before the session starts)
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31.05.2025 | SESSION-1 | HALL-2

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. Dr. İlker YÜCE

Authors	Affiliation	Presentation title
Fatma ŞAHİN	Hacı Bayram Veli University	The Influence of Social Media Influencers on Generation Z: An Examination of Purchasing Behaviors and Digital Opinion Leadership
Pınar AKALAN Arzu ÖZMERDİVANLI	Karamanoğlu Mehmetbey University	Digital Transformation in the Insurance Industry: Insurtech
Büşra ERKEÇOĞLU Müne AKTAY	Nişantaşı University	An Examination of Life Orientation in Adults Working with Individuals with Special Needs
Emine KAYA Birgül ALAKAŞ Merve ÇELİK	Bingöl University	The Relationship between Financial Well-Being and Psychological Burnout: An Empirical Research
Merve ÇELİK	Bingöl University	Can False Self Be Functional?
Elife Neval KAR Serbay DURAN	Adiyaman University	Investigating Teaching Microeconomics with Mathematical Competence: The Case of Political Science and Public Administration Department
Şule FIRAT DURDUKOCA Arzu DERYA TAŞÇI	Kafkas University	An Examination of Pre-Service Teachers' Cognitive Structures Related to Concepts Associated with Future Literacy
EZGİ EMEL ŞAHİN	Istanbul Nisantasi University	Relationship between Anxiety Level on Adults and Childhood Trauma and Parental Attitude

(All speakers required to be connected to the session 10 min before the session starts)
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31.05.2025 | SESSION-1 | HALL-3

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Kholoud Khaled Mustafa ELMABRUK

Authors	Affiliation	Presentation title
Emil SHUKURLU Sevda A. MURADOVA	Azerbaijan Medical University	Antimicrobial Potential of Livid Pigweed (*Amaranthus lividus* L.)
Usman SAMA'ILA	Umaru Musa Yaradua Unıversıty	Islation and Idenfication of Fungal Species Associated with the Tiger Nut Drink in some Tertiary Institution within Katsina Metropolis
Dariyanti Ebrahim MOHAMMED	Gujarat University	The Impact of International Accounting Standard (Ias 41) on Agricultural Financial Reporting a Systematic Literature Review
Shagufta SAEED Aneesa NISAR	University of Veterinary and Animal Sciences-UVAS	Green Synthesis of Zinc-oxide Nanoparticles Using *Achyranthes aspera* Leaf Extract and Their Potent Action against the Poultry Pathogens
Umar Rabiu BELLO	Umaru Musa Yar'adua University	Phytochemical Screening and Antimicrobial Activities of Leaves Extract of **Dodonaea viscosa* Linn
Benlahrache Nour El HOUDA Boufercha OUMEIMA Boubendir ABDELHAFID Benhizia YACINE Goudjil HAYET	Abdelhafid Boussouf University	The Valorization of *Coriandrum sativum*
Sahil CHAUDHARY Barinderjit SINGH	I.K. Gujral Punjab Technical University	Upcycling Grapefruit Peel Waste for Muffin Fortification: Characterization of Physical, Bioactive, and Microstructural Properties
Huma IKRAM Sania AJAZ Darakhshan J. HALEEM	University of Karachi	Repurposing N-acetylcysteine: Unveiling Its Potential for Memory Enhancement in Animal Model

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31.05.2025 | SESSION-1 | HALL-4

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Farhan AADIL

Authors	Affiliation	Presentation title
Aderinsola E. KAYODE	South Africa Trinity University	Integrating AI Tools into Higher Education Curricula: A Multidisciplinary Approach
Vasileva Elizaveta VASILEVNA Kiseleva Marianna VLADIMIROVNA	Russian State University	Research of Fashion Trends in Wedding Fashion
Lotoreva Yuliana IGOREVNA Kiseleva Marianna VLADIMIROVNA	Russian State University	Scientist's Intellectual Assistant: The Role of Chatgpt in Innovation
Mohcin ELKHATIR Chaymae GHAFFOULI Bouchra LOUASTE Abdelkarim ELKHATIR Youssef ABOUSSALEH	Ibn Tofail University	Effect of Dietary Habits on Cognitive Performance in Primary School Students: A Cross-sectional Study in Khemissat Region in Morocco
Sekinat ABDULKAREEM Foluke Olanike FABUNMI	Federal University of Technology	Hindrances to Commercial Banks Involvement in Real Estate Development Minna, Nigeria
Asel PAZYLOVA	Osh Technological University	Analysis of the State of Foreign Investment Attraction in the Regions of Kyrgyzstan
Jalilova Sayali SAHAD	Baku State University	Creative Tour Planning
Msatfa ZOUHEIR	University Hassan First Morocco	Financial System Structure and Business Financing in Morocco

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31.05.2025 | SESSION-1 | HALL-5

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Abdulsalam Ajı SULEIMAN

Authors	Affiliation	Presentation title
S. HADDAD M.A. YALLESE	FST, University 8 May 1945	Modeling and Multi-Objective Optimization of Surface Roughness and Material Removal Rate in Peek Cf30% Turning Using Rsm and Desirability Function
Ghizlane RAHIL Imane RAHIL Mustapha OUJAOURA Walid BOUARIFI	Mathematical Team and Information Processing National school of applied sciences SAFI	Feature Extraction and Analysis Techniques for Human Motion Understanding in Images and Videos
Zerouk BEKRI Adel MOKHTAR Rachida RAHMANI Mourad OUANID Fatma CHERGUI Mohammed HACHEMAOUI Bouhadjar BOUKOUSSA	University of Relizane	Using Synthetic Zeolite Y from Natural Clay to Improve Carbon Dioxide Adsorption Using Ion Exchange
Rajaa DIANY Mohammed SALAH Abdessamad TOUNSI	Sultan Moulay Slimane University	Phenylazonaphthalene-based Azo Dyes are Modified Chemically to Enhance Their Photovoltaic Qualities for Use in DSSCs. DFT and TD-DFT Analysis
Rawia Nasri Regaya KSIKSI Salma DAOUD Mohamed Faouzi ZID	University of Tunis El Manar	Synthesis of New Decavanadate Material Na_2 [H4V10O 28]14H_2O: Characterization and Biological Activity
Yimesgen Mehari KEBEDE Awoke Andargie TIRUNEH Endalew Getnet TSEGA	Bahir Dar University	Crank-Nicolson Method for Singularly Perturbed Unsteady Parabolic Problem with Multiple Boundary Turning Points
Sikirulai Abolaji AKANDE Quadri Opeyemi RAUF Ojeba Innocent MUSA Samuel Oloruntobi JOB AbdulMalik Olawale OKUWOBI Jamiu Olarenwaju AKANDE	Federal University of Technology	Mathematical Assessment of Enrofloxacin Dosing in Canine UTIs: A Preliminary Model-Based Approach for Veterinary Practice
Mohamed El HOUSSE Abdallah HADFI Ilham KARMAL Mustapha NASSIRI Sara DARBAL Nour Eddine IBERACHE Imane AMMAYEN Said Ben-AAZZAA M'barek Belattar a et Ali DRIOUICHE	University Ibn zohr	Investigating the Potential of Food Waste as an Interesting Source of Green Scale Inhibitors

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31.05.2025 | SESSION-1 | HALL-6

Ankara Local Time: 10:00-12:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. Melike KAYA

Authors	Affiliation	Presentation title
Afaq AHMAD Basant KUMAR Nassor S. N. Al JAHWARI Reena ABRAHAM	Modern College of Business and Science	Integrating Iot Sensor Networks with Morphological Image Processing for Enhanced Precision Agriculture
Diellorita ABAZI	International University of Struga	Sustainable Rural Development through Advanced Agricultural Practices and Food Security in the Western Balkans
P. PRATHEESHA K.S. Suresh KUMAR	University of Kerala	Food and Beverages Industry; Customer Loyalty as the Key Component
S.A. IGWESHI R.O. ANYASI	University of South Africa	Indole Acetic Acid (IAA) and Its Growth Multiplication Parameters in the Control of Soil Organic Pollution
Emmanuel Tomisin BELLO Sunday AWE Akanbi-Gada Mariam BIOLA	Kwara State University	Nanobiotechnology: Transforming Food Safety and Microbial Diagnostics through Nanoscale Innovation
Bhabajyoti SAIKIA	Assam Down Town University	Managerial Insights into Circular Economy Strategies in the Food Industry
Titus Wuyah YUNANA	Nigeria Police Academy	Economic Analysis of Sugarcane Production in Numan Local Government, Adamawa State-Nigeria
Bourenine KAHINA Nait KACI-BOUDIAF Malika SAADOUN NORIA	Mouloud Mammeri University	Grenadine Molasses: Between Promises and Challenges

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31.05.2025 | SESSION-2 | HALL-1

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Muhammed KÜPE

Authors	Affiliation	Presentation title
Çağlar ERARSLAN Oğuz ERDEM	Hidroan Ankara Hydraulic Machine Ind. Tra. Ltd. C.,	The Machining Parameters and Application Areas of Laser Beam Cutting (Lbc) Method
Hayrettin GÜRBÜZ Yavuz EKİNCİOĞLU	Bayburt University	Modeling of Semiconducting Polymer–Gas Interactions Using Dft: The Case of 2-Pani
Meryem BUZ EGİ Mustafa DURGUN Mustafa KAYA Saliha ÖZARSLAN	Harran University	Investigation of Hydrogen Production from Methanolysis of Sodium Borohydride in the Presence of Copper/Cobalt Complex-Supported Catalysts
Muhammed KÜPE Özkan KUFACI	Ataturk University	Effects of Different Nutrient Element Applications on the Vegetative and Generative Development of Narince and Karaerik Grape Varieties Grown under Greenhouse Conditions
Semra ZEREN Esra KARATAŞ Mustafa ALTIN	Sivas University of Science and Technology	On the Conformal* Curvature Tensor in Riemannian Submersions with Quarter-Symmetric Non-Metric Connections
Serdar ÇAKIR Burak Can ÖZER	Tectone Technology Industry and Trade Inc.	Development of Illuminated Feedback in Hob Control
Duriye KÖK Özge Hande YALÇIN DURAK	Yorglass Glass Ind. And Tra. A.C.,	Thermal Stability Analysis of Hydrophobic Sol-Gel Coatings on Glass Surfaces Used in the Home Appliance Industry as a Function of Curing Temperature
Batuhan KAYHAN Onur ERTUGRUL	Izmir Katip Celebi University	The Effect of Plasma Surface Treatment Parameters and Adhesive Type on The Bonding Strength of Next-Generation Aluminum and Composite Sheets
Merve Gül TÜLEK Mustafa ASLAN Merve Esranur YALÇIN Kutay ÇAVA Hüseyin İPEK	Karadeniz Technical University	Production of Hybrid Thermoplastic Composites Reinforced with Hemp and Basalt/Carbon Fabrics for Automotive Interior Trim Panels and Determination of Their Mechanical and Thermal Properties

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31.05.2025 | SESSION-2 | HALL-2

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Selim ÖZDEMİR

Authors	Affiliation	Presentation title
Burhan BAHADIR Ufuk KARADAVUT	Bingöl Provincial Directorate	Evaluations On The Relationship Between Precipitation And Agricultural Yield
Burhan BAHADIR Ufuk KARADAVUT	Bingöl Provincial Directorate	Assessment of Climate Indices in Bingol Province
Muharrem ERGUN Nazan ERGUN Bülent KAYA Esra BALKİS	Bingöl University	Postharvest Quality of 'Ağin Beyazi' Grape by Green Synthesis of Calcium Nanoparticles from Sideritis Pisidica
Nazan ERGUN Sezai ERCİŞLİ Muharrem ERGUN	Atatürk University	Wild Plants That Are Consumed as Vegetables in the Province of Bingöl
Üzeyir ÖZOĞUL Muhammed KÜPE	Üzümlü District Directorate of Agriculture and Forestry	Aronia melanocarpa: A Prominent Fruit within the Berry Family
Üzeyir ÖZOĞUL Muhammed KÜPE	Üzümlü District Directorate of Agriculture and Forestry	Research on Turkish Grapevine Genetic Resources and a Local Example from Erzincan, Karaerik cv.
Rıdvan UÇAR Selim ÖZDEMİR	Pamukkale University	Evaluating the Potential of Lavender as Bee Pasture
Fethiye SAĞKAN	Zonguldak Bülent Ecevit University	The Role of Pharmacies in Cold Chain Medicines Management and Nanotechnological Approaches
Muammer EKMEKÇİ Selim ÖZDEMİR Rıdvan UÇAR Kağan KÖKTEN Erdal ÇAÇAN Mahmut KAPLAN	Bingöl University	Effects of Base Fertilizer Applications on Silage Quality of some Silage Corn Varieties

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31.05.2025 | SESSION-2 | HALL-3

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Andrey POPATANASOV

Authors	Affiliation	Presentation title
Andrew Ayodeji AJAYI Catherine Adesoye FAMOSAYA Complete Emem SAMBO	Obafemi Awolowo University	Oxidative Stress Impact of Toxic Heavy Metals on Giant African Land Snails (*Achatina achatina* and *Achatina fulica*).
S. MUNEESWARI	SRM Institute of Science and Technology	Optimizing Performance and User Experience in Online Food Delivery Platforms Using Databricks and Delta Lake
O.F. OJO C.V. DIKE C.N. ALEKE	University of Nigeria	Mortality Risk Management Practices among Poultry Farmers in Enugu State, Nigeria
Amira Chahrazad BENABDELHAK Hanane DERBAK Hanane TITOUAH Sofiane AISSANOU Abdelhanine AYAD	University of Bejaïa	Impact of Avian Coccidiosis on Intestinal Integrity: Damage Quantification Through Histomorphometric Analysis
Hanane TITOUAH Amina RAHMANI Sofiane AISSANOU Mokrane Iguer-OUADA	Université de Bejaia	Influence of Water Temperatures on the Dynamics of Spermatogenesis in Wild *Flathead mullet mugil cephalus* (Linnaeus, 1758).
Skender DEMAKU Shega ELSHANI Arbnorë ALIU Donika SYLEJMANI	Université de Bejaia	Determination of Nitrate Ions (NO_3^-), in Red Meat of Animals, in the City of Pristine, through the Instrument &Quot; Green Test ECO 5 F-ANMEZ
Andrey POPATANASOV	Bulgarian Academy of Sciences, Institute of Neurobiology	Cytokinin Hormopriming and the Germination of some Solanaceae Crop Varieties from Bulgaria
R.U. BAKO H. SALLAWU A. ABDULLAHI A. I. OSHEGHALE D. I. UTOLOR	Federal University of Technology Minna	Effect of Insurgency on Income of Marketers in Chikun Local Government Area of Kaduna State, Nigeria

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31.05.2025 | SESSION-2 | HALL-4

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Prof. Dr. Sivaram MURUGAN

Authors	Affiliation	Presentation title
J. R. OLASINA O. H. ALIU	Federal Polytechnic Ilaro, Ogun State	Engineering an Automated Model for Food Classification (CNNAFCM) Based on Pictures of Nigerian Indigenous Lunches with the Purpose of AI in Agriculture
Hassina Hafida BOUKHALFA Naoual GUEHILIZ	Mohamed Khider University of Biskra	Assessing the Environmental Consequences of Plant Protection Measures in Algerian Arid-Zone Cereal Farming
Hassina Hafida BOUKHALFA Fatima Zohra BENSALEM	Mohamed Khider University of Biskra	Influence of Local-Imported Wheat Mixtures on Couscous Quality
Hassina Hafida BOUKHALFA Selma REZIG	Mohamed Khider University of Biskra	Assessment of Water Quality for Livestock Consumption
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Feeding the Future Metropolis: Vertical Farming as Urban Infrastructure
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Architectural Logistics for the Urban Food Grid: Cold Chains, Storage, and Design
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Zero-Kilometer Architecture: Design Strategies for Hyperlocal Food Systems
Melik SAMI Khelil SARA Tallal ABDEL Karim BOUZIR	Mohamed Khider Biskra University	Public Space as Food Infrastructure: Activating Parks and Plazas for Edible Urbanism

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31.05.2025 | SESSION-2 | HALL-5

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. Dr. Ecem KARA

Authors	Affiliation	Presentation title
C.VIJAI S SINDHUJA	R&D Institute of Science and Technology	Water Management Techniques for Drought Prone Agricultural Areas
C.VIJAI V. Uma MAHESWARI	R&D Institute of Science and Technology	Organic Farming and Its Role in Sustainable Agriculture
Pratibha SINGH	Manav Rachna International Institute of Research and Studies	Value Added Product Development Incorporated with Hemp Seed
Bouchra BOURHABI Latifa MOUHIR Souad TAYANE	Hassan II University	Assessing the Suitability of Surface Water from Bin El Ouidane Reservoir for Agricultural Irrigation in Morocco
Bouchemal AMINA Inouri AHLEM Ladouali ZEYNEB Mechiah FAHIMA Benhoula MOHAMED	Campus Universitaire	Lactic Acid Bacteria: Functional Diversity and Emerging Applications
K. HBYAJ D. HMOUNI A. El OUALKADI	National Institute of Agricultural Research	Contribution of Seed Morphometric Characterization to the Identification of Indigenous Moroccan Grapevine Cultivars
Aicha El OUALKADI Yousra ZANTAR IMane NAHRO Fatima GABOUN	National Institute of Agricultural Research	First-Generation Screening of Gamma-Irradiated Strawberry Plants for Agronomic and Quality Traits in Morocco
Aleena MARYIAM Hamid SAEED	Punjab University College of Pharmacy	Coloaded thermosensitive system of irinotecan and curcumin nano-vesicle for colorectal cancer targeting, in vitro and in vivo investigation

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31.05.2025 | SESSION-2 | HALL-6

Ankara Local Time: 12:30-14:30

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Porkodi SIVARAM

Authors	Affiliation	Presentation title
Sushmita BANDYOPADHYAY Soham GOSWAMI Mahua Nandy PAL	MCKV Institute of Engineering	Revolutionizing Agriculture: The Synergy of IoT and AI in Crop Monitoring
Selorm OMEGA	University of Cape Coast	The Role of Agricultural Technology Use in Enhancing Sustainable Food Systems of Smallholder Soybean Farming in Northern Ghana
Abu RAHAD A.K.M. Afzal HOSSAIN Md Al-EMRAN Md Mahiuddin ZAHANGIR Md SHAHJAHAN	Bangladesh Agricultural University	Spirulina to the Rescue: Boosting Tilapia Growth Under Pesticide Stress
Amarachi Linda OBINNA Ndubuisi Samuel MACHEBE Chijioke Cornelius NWOGA Chigozie Bright AMAEFULE Ikenna Paulinus UMEUGWUOKE	University of Nigeria	Phytochemical Analysis of Avocado Leaves and Turmeric
Samuel Seun SALAKO Kanyinsola Gloria ADESOLA	Federal Polytechnic Ilaro Ogun State	Role of Urban Planners in Promoting Energy-Efficient Screen House Tomato Production in Urban Areas; a Case Study of Yewa North Local Government Area of Ogun State
Muhammad IMRAN	Government College University	Nutritional Composition and Health Benefits of Bitter Melon
Fatima Zahra SAYERH Latifa MOUHIR Laila SAAFADI	Hassan II University	Hospital Wastewater as a Silent Vector: Microbial Contamination and Antibiotic Resistance at the Human Health-Environment Interface
Fatima Zahra DAHMANI Jamila DAHMANI Nadia BELAHBIB	Animales et Agro-industrie	Anacyclus pyrethrum:une espèce médicinale menacée entre valorisation ethnobotanique et conservation durable
Oumaima. El MTIOUY Hamid ESSABIR	Ibn Zohr University	Valorization of Agricultural Waste in Sustainable Biocomposites: Enhancing Mechanical Properties with Natural Fiber Reinforcements

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31.05.2025 | SESSION-3 | HALL-1

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Selçuk KODAZ

Authors	Affiliation	Presentation title
Ali İhsan ÖZÇETİN Nihat ATMACA Adem ATMACA	Gaziantep University	Assessment of Life Cycle Embodied Energy and Related Co_2 Emissions, a Case Study of Historic College Building in Gaziantep
ALEYNA PALA	Istanbul Nisantasi University	University Students' Mindfulness Levels and Depression Levels and Their Relationship with Their Tendency to Receive Psychological Support
Bahar ARABACI Sibel GÖK	Marmara University	Examining the Emotional Reflections of Voice Behaviors in Organizations: An Employee Perspective
Pınar YÖRGÜÇ Sibel GÖK	Marmara University	A Study on the Work Values of Generation Z Employees
Mehmet Akif ARDUÇ Harun YALÇIN	Mehmet Akif Ersoy Secondary School	A Study on the Reasons for Not Implementing in-Class Science Experiments
SÜMEYYE AYDOĞAN ŞULE BAŞTEMUR	Ordu University	Examination of Thesis Conducted on Sexual Abuse in Turkey between 2014 and 2024 Through Document Analysis Method
Ebru KARAKUŞ BAŞAR Hatice ÇINAR	Selcuk University	The Effect of Concept Cafes on Spatial Perception: The Case of Dudu Firin-Kahve
Suat ERDOĞAN	Düzce University	Zakat and Wealth Measures in Islamic Law

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31.05.2025 | SESSION-3 | HALL-2

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assoc. Prof. Dr. Gürsel ÖZKAN

Authors	Affiliation	Presentation title
Fatma Nur BÜLBÜL Şenol YILDIZ	Bolu Abant İzzet Baysal University	Suppressive Potential of Entomopathogenic Nematodes (EPN) in Biological Control of Pest Species
Sude AVCI Şenol YILDIZ	Bolu Abant İzzet Baysal University	Antagonistic Fungi in Plant Parasitic Nematode Management: Species, Application Methods, and Field Efficacy in Vegetables
Mehmet ZENGIN İbrahim ÇETINER	Burdur Mehmet Akif Ersoy University	Technical Specifications of Prismatic Balers
Murat BİLİCİ Eyüp BAGCI Nurgül Bilici Azize DEMİRPOLAT	Firat University	Aromatic Potentials of *Mentha longifolia* subsp. *longifolia* L. Essential Oils: Insights from GC-MS Profiling
Merve MACİT	Bingöl University	The Importance of Utilization of Blackthorn (*Prunus spinosa* L.) Waste Seeds by Different Extraction Methods
Meziyet NARIN	Balıkesir University	Cultural Tourism Potential of Savaştepe Saribeyler
Meziyet NARIN	Balıkesir University	Sustainable Marine Tourism: The Case of Burhaniye
Ersin TURAN Gürcan SAMTAŞ	Düzce University	Pneumatic Proportional Valve Control with Fuzzy Logic
Yasin GÖRMEZ Halil ARSLAN Vedat ÖNAL Veysel GÜNDÜZ	Sivas Cumhuriyet University	Fine-Tuning a BERT-Based Model for Automated Classification of CVE Records Using CVSS Metrics

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31.05.2025 | SESSION-3 | HALL-3

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Elena SKVORTSOVA

Authors	Affiliation	Presentation title
O b Adebisi LUKE O. Oludare TOMISONA	b Agricultural and Rural Management Training Institute (ARMTI)	Exploring Gender Differences in Risk Behaviour and Profit Margins of Orange Flesh Sweet Potato Producers in Osun State, Nigeria
Elena SKVORTSOVA Oksana FILINSKAYA	Yaroslavl State Agrarian University	Cranio-Caudal Gradient in the Distribution of Microbiota of the Gastrointestinal Tract of Sheep
Dip SAHOO Avishek BARDHAN	The Neotia University	Opportunities in Breeding and Seed Production of Koi Carp and Goldfish: A Comparative Study
Preye OFUNAMA Oguntade Stephen KAYODE	School of Agricultural Technology, Federal Polytechnic, Ekowe	Farm Management Tools for Productivity: A Comparative Analysis with Lean Tools
Simran Dhingra	I.K Gujral Punjab Technical University	Isolation of Polyphenols from Jackfruit Pulp and Their Incorporation into Chitosan-Based Edible Films with Antioxidant Properties
Shreya	I.K Gujral Punjab Technical University	Development of Broccoli-Infused Barnyard Millet Pasta
Vera Renta Siahaan Renny Sinaga Safrina Daulay	Polytechnic of Health Ministry of Medan	A Study on The Characteristics of Pregnant Women Concerning Stunting At The Midwifery Clinic in The Bahkapul Health Center Working Area
Sehrish Firyal Hira Anwar Shagufta Saeed	University of Veterinary and Animal Sciences	Genetic analysis of Complement Component 5 Gene in Mastitic cows
U. H. ANYANWU L. E. DANIEL	Federal Polytechnic Ekowe, Bayelsa State	Use of Insects as Alternative Protein Sources in Poultry Feeds: A Review

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31.05.2025 | SESSION-3 | HALL-4

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Dr. Mehzabin REHMAN

Authors	Affiliation	Presentation title
Salim Abdullahi GWARJO Zainab Ahmad MUHAMMAD	Umaru Musa Yar'adua University	Qualitative Phytochemical Analysis of the Fresh and Processed *Capsicum annum* (Pepper) and *Solanum lycopersicum* (Tomato) Using Ethanolic Extracts
Gjok VUKSANI Angjelina VUKSANI	Agricultural University of Tirana	Grafting Compatibility and Morphological Performance of *Cupressus arizonica* and *Calocedrus decurrens* on *Cupressus sempervirens* under Mediterranean Conditions
Olufolake. E. ADELAKUN Kerimat.O. BASHIRU	University of Ibadan	Exploring the Digital Literacy Proficiency of Rural Youths in Ona-Ara Local Government Area, Oyo State
Mehzabin REHMAN	University of Science and Technology Meghalaya	Evaluation of Growth Parameters and Antioxidant Defense Mechanisms on Mung bean (*Vigna radiata* (L.) Wilczek) under Arsenic stress
M. EL-FECHETALY A. KHALLOU S. CHERRIET B. HAMMOUTI K. EL BEKKAYE M. IBRIZ	Ibn Tofail University	Characterization of Fungal Agents Responsible for the Leaf Decline of Olive Trees in the Oriental Region of Morocco
Adegbola OLUWATOSIN Oluwabukola &AMP Oloyede Taiwo PETER	Adegbola Oluwatosin Oluwabukola & Oloyede Taiwo Peter	Proteins Linked to Colon Cancer: Systematic Review
B. O. OYEFESO B. F. TIJANI O. E. EDU	University of Ibadan	Mass and Volume Modelling of Cashew Fruits Using the Geometrical Attributes
Somnath BERA Anwesha MUKHERJEE Debashis DE	Maulana Abul Kalam Azad University of Technology	FedSoil: A Joint Time and Energy-efficient Federated Learning-based Soil Health Monitoring Framework
Sanjay Subramanian.S Sandeep.A Thirumurugan.V Sabarish.R Thiyagarajan.G.M S. Pavai Madheshwari M. Meena R. Subhashini Priyadharshini	R.M.K Engineering College	Wildsentinel: Ai-Powered Wildlife Crossing Detector for Remote Forests
Maria Duarte BELLO	School of Social Communication and Media Studies Polytechnic University of Lisbon	Networking with Purpose: How to Build Relationships that Connect and Propel

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31.05.2025 | SESSION-3 | HALL-5

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Res. Assist. Zeynep YUMLU

Authors	Affiliation	Presentation title
Suleiman Ibrahim INUWA Muhammad Saleh SANI B. Vijay KUMAR Karthik HP Yedida SUDHAMINI	SR. University Warangal	Total Factor Productivity and Supply Response of Wheat Production in Nigeria: An Empirical Analysis Using Törnqvist-Theil Index and ARDL Model
Karima LAAROUSSI Saloua JEMJAMI Assia HARKANI Tarik BENABDELOUAHAB Abdellah EL AISSAOUI	University Hassan 1st	Spatial, Temporal, Economic, and Environmental Analysis of Water Pumping Systems in Three Arid Regions
Nabi FAHIMA	Université Dr Yahia Farès de Médéa	Nutritional Influence on Milk Composition and Output in Dairy Cattle from the Mitidja Plain
Rania Rahmani Amel AIT MEDDOUR Mohammed BENHOULA Samia HAMMA-FARADJI Kahina BELBACHIR Sylia TERKI	University of Bejaia, Faculty of Natural and life Sciences	Formulation of an Artisanal Fresh Cheese Incorporating Probiotic Lactic Acid Bacteria
Ruhani	I.K. Gujral Punjab Technical University	Crafting Nutrient Rich Biscuits with Buckwheat Amaranth and Wheat Flour
FERROUDJ NAWAL KHADRAOUI JIHANE DAGUIANI KAOUKAB BOUHECHICHE DOUNIA KRID ASMAIKRAM	Laboratory of Biotechnology, National Higher School of Biotechnology	Optimization of Hydrolysis Parameters for Maximum Total Sugar Extraction from Vegetable Peel Waste Using Thermo-Chemical Hydrolysis
Chokri BAYOUDH Malek BEN ALI Afifa MAJDOUB Taoufik BETTAIEB	Regional Research Centre on Horticulture and Organic Agriculture	Study of *in Vitro* Propagation and Selection for Salt Tolerance of Local *Opuntia cactus*
Ilona BITAROVA Giorgi DUGASHVILI	Grigol Robakidze University	Governance, Digitalization And Medical Record Privacy: A Legal and Ethical Inquiry
Kunika GANDOTRA Barinderjit SINGH	I.K. Gujral Punjab Technical University	Development, Standardization, and Consumer Acceptance of Nutrient-Enriched Healthier Brownie Made with Alternative Flours and Natural Ingredients

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31.05.2025 | SESSION-3 | HALL-6

Ankara Local Time: 15:00-17:00

Meeting ID: 860 5266 6988 | Passcode: 303132

HEAD OF SESSION: Assist. Prof. Dr. Zeshan IQBAL

Authors	Affiliation	Presentation title
Michael Sheila OJEI	Admiralty University of Nigeria	Urban Agriculture and Food Security in Cities
H.O. SADIQ B.T. ADEYEMO Y.O. BUSARI	University of Abuja	Growth Performance and Haematology Effects of Dietary Mixture of Ginger (*Zingiber officinale* L.) and Garlic (*Allium sativum* R.) on Catfish (*Clarias gariepinus* Bruchell 1822) Juveniles
Darwin H. PANGARIBUAN Koes HENDARTO Anggun ANGGRAINI	Universitas Lampung	Growth, Yield and Quality Response of Sweet Corn (*Zea mays* L. Saccharata Sturt) on the Application of Biofertilizer Dan Tricho-Compost
Chira Maria-NATALIA	University of Suceava	Influence of Heavy Metal Concentration on the Distribution between Macronutrients in Goat Milk
Arben TËRSTENA Gazmend DEDA Ismail MEHMETI Fatime RAMADANI Nuredin KRIVANJEVE	University of Applied Sciences in Ferizaj	The Role of Technological Innovation and the Circular Economy in the Development of SMEs in the Agricultural Sector
Asmaa SAYAH Karim BENHENIA	High National Veterinary School	Optimizing Goat Semen Cryopreservation: Impact of Extender Type on Post-Thaw Sperm Quality
Kanika SHARMA	I.K. Gujral Punjab Technical University	Development of Whole Wheat Biscuits Fortified with *Musa* Species (Paradisica) Inflorescence
Habil. Cristina Raluca Gh. Popescu	University of Bucharest	Development Through Research and Innovation: Türkiye's Strategic Advantage for Cross-Continental Artificial Intelligence Collaboration
Loredana Mariana HUȚUȚUI Sonia AMARIEI	University of Suceava	Development of Intelligent Packaging Systems for Real-Time Detection of Meat Spoilage

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SYMPOSIUM PHOTOS




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ABSTRACTS

ANTINEOPLASTIC PRODUCTION OF DRUG RESISTANT GLOVES

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ABSTRACT

As a result of studies conducted in the field of diagnosis and treatment in relation to the increase in the number of cancer cases, drug groups defined as antineoplastic drugs are being studied, and these drugs are being used in cancer treatment processes. Healthcare workers are exposed to these drugs through inhalation, ingestion or direct skin contact during the preparation, transportation, application during treatment, storage and disposal of waste.

Different protective equipment is preferred to eliminate the possible negative consequences that may arise because of exposure to drugs. To prevent skin exposure, the use of chemotherapy gloves has become a necessity.

As a result of this need, ESTAŞ A.Ş. developed a chemotherapy glove production project. The prescription for non-sterile, powder-free examination gloves currently produced by the company was studied and changes were made. Before applying the final prescription to the mass production line, prototype production was carried out on the robotic mini production line and optimization studies were carried out on the prescription. Physical, dimensional and leakage tests were applied to the gloves that were visually accepted as suitable from the sample production and the prescription accuracy was validated for the glove with the most suitable values according to national norms. The validated prescription was adapted to the mass production line. Resistance tests were performed on the gloves produced in the mass production line using 12 different drugs preferred against chemotherapy gloves within the scope of ISO 6529 and ASTM D6978 standards. These tests were applied by an accredited laboratory and their permeability to chemotherapy gloves was proven.

Keywords: antineoplastic drugs, chemotherapy gloves, Gloves, Protective Equipment

A COMPARATIVE DOSIMETRIC STUDY USING FIELD-IN-FIELD, INTENSITY MODULATED AND VOLUMETRIC ARC MODULATED RADIOTHERAPY TECHNIQUES IN TERMS OF CARDIAC SUBSTRUCTURES EXPOSURE FOR LEFT-SIDED BREAST CANCER RADIOTHERAPY

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ABSTRACT

Introduction: The standard of care following breast-conserving surgery is adjuvant radiation which decreases locoregional recurrence and improves survival rates. However, cardiovascular events following radiotherapy have emerged as the primary cause of death from non-breast cancer in these patients. Due to the proximity of cardiovascular structures to the treatment field, patients with left-sided breast cancer require special attention. The present study aimed to evaluate the organ at risk (OAR) and cardiac substructures dosimetry of left-sided breast cancer radiotherapy comparatively with three different radiotherapy techniques: Field in field (FIF), IMRT and VMAT.

Material and Methods: Ten patients with early-stage left-sided breast cancer underwent breast-conserving surgery were included in this study. Patient's simulation scans were used and field-in-field (FIF), intensity-modulated radiation therapy (IMRT), and volumetric-modulated arc therapy (VMAT) plans were created for each patient. Heart, lungs, contralateral breast and cardiac substructures (left anterior descending artery, atriums, ventricles, pulmonary artery, ascending and descending aorta) were delineated. The dose received by these structures and planning quality were compared dosimetrically. An additional analysis was also undertaken to evaluate the correlation between breast volume and resulting radiation dose to nearby structures.

Results: For the planning quality, there was better homogeneity for modulated plans compared to FIF. For the doses to the OARs and cardiac structures, lower doses were generally achieved with the FIF plan. When the association between the breast volume and the dosimetric parameters was evaluated, it was observed that as breast volume increased, normal tissue doses increased.

Conclusions: The selection of the planning modality should be made according to the patient's baseline characteristics including age and cardiovascular risk factors. Conformal planning seems to be the most appropriate treatment for left-sided breast cancer radiotherapy.

Keywords: Breast cancer, radiotherapy planning, cardiac substructures, dosimetric parameters

THE EFFECT OF A HEALTHY NUTRITION PROGRAM ON OBESITY, SELF-ESTEEM AND IDENTITY DEVELOPMENT FOR HIGH SCHOOL STUDENTS

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ABSTRACT

During adolescence, the individual tries to adapt to new developmental characteristics and also seeks a new identity. Especially today, when the increase in fast-food consumption is combined with the effect of technology, obesity can be seen quite frequently. Obesity does not only cause health problems but also can cause very important problems on the self-esteem of the adolescent. Under these thoughts, the project aimed to examine the effects of fast-food consumption and eating habits on obesity and self-esteem during adolescence. Quasi-experimental design, one of the quantitative research methods, was used in the research. The research was carried out in a high school determined by random sampling method from the high schools affiliated to the Çankırı Provincial Directorate of National Education. In the study, data were collected with the "General Information Form", the "Eating Habits Scale for Adolescents" adapted to Turkish by Yılmaz (2021), the "Spiritual Development Scale in Adolescence" developed by Uzun (2018), and the "Identity Scale" adapted to Turkish by Coşkun (2004). After the implementation of the 10-week training program, the "Eating Habits Scale for Adolescents", "Identity Scale" and "Spiritual Development Scale in Adolescence" were re-applied as the post-test. As a result of the research, it was determined that children in adolescence frequently consumed fast food and did not have breakfast, and the scores obtained in the mental health and identity dimensions were at a level that could be damaged. It was determined that the implemented training program changed the eating habits of children in adolescence and had positive effects on mental health and identity development. Based on the data obtained as a result of the research, it can be recommended to organize nutrition education programs for children and mental health and identity formation trainings, especially for children in adolescence and individuals in early adulthood.

Keywords: Fast food, Obesity, Adolescence, Self esteem

BIBLIOMETRIC ANALYSIS OF STUDIES ON THE EFFECTS OF PILATES EXERCISES ON CHRONIC PAIN MANAGEMENT

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ABSTRACT

Objective: This bibliometric analysis aims to provide a comprehensive view of the literature on pilates exercises and chronic pain management, identifying research trends, key authors, institutions, and countries, and analyzing influential publications and research areas to highlight potential gaps for future studies.

Method: This article presents a comprehensive bibliometric analysis using the Biblioshiny application of the Bibliometrix package in R programming and the VOSviewer tool. In this study, 110 relevant articles published between 2002 and March 2024 in the Scopus database were analyzed.

Findings: Brazil is a leading country both in terms of publication output and in pioneering international collaboration efforts. The article 'Exercise Therapy for Fibromyalgia', published by Angela J. Busch (2011) in the journal 'Current Pain and Headache Reports', is the most cited paper with 217 references. The study also identifies the top three journals with the highest number of publications: the first being 'Journal of Bodywork and Movement Therapies', the second 'BMC Musculoskeletal', and the third 'Physical Therapy'. Notably, 'Universidade Cidade de São Paulo' stands out as the institution most involved in this research area due to its prolific research output. The most published author is ' Cristina Maria Nunes Cabral', with 14 articles. Commonly used keywords include 'low back pain', 'pilates', 'rehabilitation'.

Results: The findings of this study serve as a valuable resource for researchers and practitioners exploring the relationship between pilates exercises and chronic pain, as well as for those interested in the practical applications and future developments in this field. This research examines the role of pilates exercises in chronic pain management, highlighting its place in physical therapy and rehabilitation, while contributing to the literature and providing a roadmap for future studies.

Keywords: Chronic pain, Pilates, Rehabilitation, Bibliometric analysis

PİLATES EGZERSİZLERİNİN KRONİK AĞRI KONTROLÜNE ETKİSİYLE İLGİLİ YAPILAN ÇALIŞMALARIN BİBLİYOMETRİK ANALİZİ

ÖZET

Amaç: Bu bibliyometrik analiz, pilates egzersizlerinin kronik ağrı kontrolü üzerindeki etkilerine odaklanan bilimsel literatüre bütüncül bir perspektiften yaklaşmayı; bu alandaki araştırma eğilimlerinin, tarihsel gelişiminin, öne çıkan yazar, kurum ve ülkelerin belirlenmesini; ayrıca en etkili yayınlar ve araştırma alanlarının sistematik biçimde analiz edilerek gelecekteki bilimsel çalışmalara yön verecek potansiyel araştırma boşluklarının ortaya konulmasını amaçlamaktadır.

Metod ve Yöntem: Bu makale Bibliometrix paketine ait Biblioshiny uygulamasıyla R programı ve VOSviewer araçlarını kullanarak kapsamlı bir bibliyometrik analiz sunmaktadır. Bu çalışmayla Scopus veri tabanında 2002 ile 2024 (Mart) yılları arasında yayınlanan 110 ilgili makale incelenmiştir.

Bulgular: Brezilya hem makale yayınları açısından önde gelen ülke iken hem de uluslararası iş birliği çabalarına öncülük etmektedir. Angela J. Busch (2011) tarafından yazılan 'Current Pain and Headache Reports' dergisinde yayınlanan 'Exercise Therapy for Fibromyalgia' makalesi 217 atıf sayısı ile en çok atıf alan makaledir. Çalışma aynı zamanda, birinci dergi 'Journal of Bodywork and Movement Therapies', ikinci dergi 'BMC Musculoskeletal, üçüncü dergi 'Physical Therapy' en çok yayın yapan ilk üç dergidir. Özellikle, 'Universidade Cidade de Sao Paulo' üretken araştırma çıktısı ile bu konu alanına en çok dahil olan kurum olarak öne çıkmaktadır. En çok yayın yapan yazar, 14 makale ile 'Cristina Maria Nunes Cabral' dır. En çok kullanılan anahtar kelimeler arasında 'low back pain, 'pilates', 'rehabilitation' yer almaktadır.

Sonuç: Bu çalışmanın bulguları, yalnızca pilates egzersizleri ile kronik ağrı arasındaki ilişkiyi araştıran bilim insanları ve uygulayıcılar için değil, aynı zamanda bu alandaki pratik uygulamalara ve gelecekteki olası gelişmelere dair kapsamlı bir bakış kazanmak isteyen herkes için önemli bir kaynak niteliğindedir. Sonuç olarak, bu araştırma pilates egzersizlerinin kronik ağrı yönetimindeki rolünü irdeleyerek, fizik tedavi ve rehabilitasyon disiplinindeki yerini vurgulamakta; bununla birlikte, ilgili literatüre anlamlı katkılar sunarak bu alanda gelecekteki çalışmalar için bir yol haritası oluşturacaktır.

Anahtar Kelimeler: Kronik ağrı, Pilates, Rehabilitasyon, Bibliyometrik analiz

EXPERIMENTAL ANALYSIS OF PHASE CHANGE MATERIAL BASED BATTERY THERMAL MANAGEMENT SYSTEM FOR DIFFERENT ENVIRONMENTAL AND DISCHARGE CONDITIONS

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ABSTRACT

In this study, the manufacturing and experimental analysis of a phase change material (PCM) based battery thermal management system (BTMS) experimental setup was carried out. In the experimental setup, cylindrical type 18650 Lithium-ion (Li-ion) battery cells were used as batteries. In the battery pack formed with four cells, aluminium shells were placed around the cells in a way that would be concentric with the cells. PCM was filled in the gap between the aluminium and battery cells. The BTMS was connected to the battery test device in a controlled temperature environment and subjected to charge-discharge cycles. In the experiments conducted with BTMS, two different outdoor temperatures (T_a) were determined as 22.5 °C and 30 °C. Accordingly, in the first, second and third experiments, T_a = 22.5 °C and the charge rate was changed to 1C, and the discharge rate was changed to 3C, 4C and 5C, respectively. In the fourth, fifth and sixth experiments, T_a = 30 °C and the charge rate was changed to 3C, 4C and 5C, respectively. In the experiments, the battery cells were subjected to five cycles for each parameter and were left to rest for 10 minutes between cycles. During the experiments, instantaneous temperature changes of the battery cells were observed using K-type thermocouples. According to the results obtained in the study, the highest battery temperatures in the first, second and third experiments were measured around 34 °C, 37 °C and 38 °C, respectively. In the fourth and fifth experiments, the highest battery temperatures were measured around 41 °C and 52 °C, respectively. In the sixth experiment, which was the most severe condition determined (T_a = 30 °C, discharge rate 5C), the temperature reached around 57 °C at the end of the second cycle, and for this reason the experiment was interrupted. Considering the temperature values measured in the experiments, it was observed that the developed PCM-based BTMS generally exhibited an effective performance in controlling the

battery temperature under different environmental conditions and discharge rates but reached the limits of the system at high discharge rates and high ambient temperatures.

Keywords: Experimental, Li-ion battery, phase change material, battery thermal management system

Acknowledgement: This study was supported by the Sivas Science and Technology University Scientific Research Projects Coordination Office with the project number 2023-GENL-Hav-0004.

FAZ DEĞİŞTİREN MALZEME ESASLI BATARYA ISIL YÖNETİM SİSTEMİNİN FARKLI ORTAM VE DEŞARJ KOŞULLARI İÇİN DENEYSEL ANALİZİ

ÖZET

Bu çalışmada faz değiştiren malzeme (FDM) esaslı bir batarya ısıl yönetim sistemi (BTYS) deney düzeneğinin imalatı ve deneysel analizi gerçekleştirilmiştir. Oluşturulan deney düzeneğinde batarya olarak silindirik tip 18650 Lityum-iyon (Li-iyon) batarya hücreleri kullanılmıştır. Dört adet hücreyle oluşturulan batarya paketinde, hücrelerin etrafına, hücrelerle eş merkezli olacak şekilde, Alüminyum kabuklar yerleştirilmiştir. Alüminyum ve batarya hücresi arasındaki boşluğa ise FDM doldurulmuştur. Bu şekilde oluşturulan BTYS, kontrollü sıcaklık ortamında batarya test cihazına bağlanarak şarj-deşarj çevrimlerine tabi tutulmuştur. BTYS ile yapılan deneylerde, 22.5 °C ve 30 °C olmak üzere iki farklı dış ortam sıcaklığı (T_a) belirlenmiştir. Buna göre birinci, ikinci ve üçüncü deneylerde T_a = 22.5 °C ve şarj hızı 1C olmak üzere, deşarj hızı sırasıyla 3C, 4C ve 5C olarak değiştirilmiştir. Dördüncü, beşinci ve altıncı deneylerde ise T_a = 30 °C ve yine şarj hızı 1C olacak şekilde deşarj hızı sırasıyla 3C, 4C ve 5C olarak değiştirilmiştir. Yapılan deneylerde, batarya hücreleri her bir parameter için beş çevrime tabi tutulmuş ve çevrimler arasında 10 dakika dinlenmeye bırakılmıştır. Deneyler esnasında, K-tipi ısılçiftler kullanılarak batarya hücrelerinin anlık sıcaklık değişimleri gözlemlenmiştir. Çalışmada elde edilen sonuçlara göre birinci, ikinci ve üçüncü deneylerde en yüksek batarya sıcaklıkları sırasıyla 34 °C, 37 °C ve 38 °C civarında ölçülmüştür. Dördüncü ve beşinci deneylerde ise en yüksek batarya sıcaklıkları sırasıyla 41 °C ve 52 °C civarında ölçülmüştür. Belirlenen en ağır koşul olan altıncı deneyde (T_a = 30 °C, deşarj hızı 5C) ise sıcaklık 2. çevrim sonunda 57 °C civarına ulaşmış, bu sebeple deney yarıda kesilmiştir. Deneylerde ölçülen sıcaklık değerleri göz önüne alındığında, geliştirilen FDM esaslı BTYS'nin, farklı çevresel koşullar ve deşarj hızlarında batarya sıcaklığını kontrol etmede genel olarak etkili bir performans sergilediği, ancak yüksek deşarj hızlarında ve yüksek ortam sıcaklıklarında sistemin sınırlarına ulaştığı görülmüştür.

Anahtar Kelimeler: Deneysel, Li-iyon batarya, faz değiştiren malzeme, batarya ısıl yönetim sistemi

Teşekkür: Bu çalışma, Sivas Bilim ve Teknoloji Üniversitesi Bilimsel Araştırma Projeleri Koordinatörlüğü tarafından 2023-GENL-Hav-0004 proje numarası ile desteklenmiştir.

BIBIOMETRIC ANALYSIS OF THE EFFECT OF SPACEFLIGHT EXPOSURE ON ASTRONAUTS IN SPACE MEDICINE

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ABSTRACT

Purpose: With the aim of contributing to the literature, this bibliometric analysis seeks to provide a comprehensive overview of the effects of spaceflight or microgravity exposure on humans or astronauts in space medicine, trace the evolution of studies, identify key contributors and impactful research areas, and offer one of the first contributions to this emerging field in our country's literature, ensuring accessibility within the field.

Method: This article presents a comprehensive bibliometric analysis using the Biblioshiny application from the Bibliometrix package, alongside R programming and VOSviewer tools. In this study, 157 relevant articles published between 2000 and 2024 were analyzed by searching the Scopus database using the keywords “space medicine,” “spaceflight,” “microgravity,” “human health,” “astronaut health,” and “impact”.

Result: The findings indicate that the USA leads in article publications and international collaboration efforts. The most cited article is "Space Radiation and Cataracts in Astronauts" by Cucinotta FA (2001), published in Radiation Research, with 308 citations. The top three journals by publication volume are NPJ Microgravity, ACTA Astronautica, and Life Sciences in Space Research. The most prolific institution is the China Astronaut Research and Training Center, while the most published author is "Li Y". The most frequently used keywords are "microgravity", "space flight", and "space radiation".

Conclusion: The findings of this study are valuable not only for researchers and practitioners in space medicine and human health but also for those interested in minimizing the effects of spaceflight on astronaut health and exploring future developments. Ultimately, this research highlights the impact of spaceflight on astronaut health, contributing to the ongoing dialogue and providing a roadmap for future studies in space medicine.

Keywords: Space flight, Aerospace medicine, Weightlessness, Bibliometric analysis.

UZAY TIBBINDA UZAY UÇUŞUNA MARUZ KALMANIN ASTRONOTLAR ÜZERİNDEKİ ETKİSİNİN BİBLİYOMETRİK ANALİZİ

ÖZET

Amaç: Literatüre katkıda bulunmak hedefiyle yaptığımız bu bibliyometrik analizle, uzay tıbbında uzay uçuşuna veya mikro yerçekimi ortamına maruz kalmanın insanlar veya astronotlar üzerine etkisiyle ilgili literatüre kapsamlı bir bakış açısı sunmayı, çalışmaların evrimini, önemli katkılarda bulunanları ve en etkili araştırma alanlarının saptanması, ülkemiz literatüründe daha çok yeni olan bu alana ilk katkılardan birini sunmayı hedefleyerek, alanda ulaşılabilir olması amaçlanmaktadır.

Metod ve Yöntem: Bu makale, Bibliometrix paketine ait Biblioshiny uygulamasıyla R programı ve VOSviewer araçlarını kullanarak kapsamlı bir bibliyometrik analiz sunmaktadır. Bu çalışmayla Scopus veri tabanında, "Uzay tıbbı, uzay uçuşu, mikrogravite, insan sağlığı, astronot sağlığı ve etki" anahtar kelimeleri taratılarak, 2000 ile 2024 yılları arasında yayınlanan 157 ilgili makale incelenmiştir.

Bulgular: Elde edilen bulgulara bakıldığında, ABD hem makale yayınları açısından önde gelen ülke iken hem de uluslararası iş birliği çabalarına öncülük etmektedir. Cucinotta Fa (2001) tarafından yazılan "Radiation Research" dergisinde yayınlanan "Space Radiation and Cataracts in Astronauts" makalesi 308 atıf sayısıyla en çok atıf alan makaledir. Aynı zamanda, "NPJ Mıcrogravity" dergisi "ACTA Astronautıca" dergisi ve "Life Scıences in Space Research" en çok yayın yapan ilk üç dergidir. Özellikle, "China Astronaut Research and Training Center" kurumu üretken araştırma çıktısı ile bu konu alanına en çok dahil olan kurum olarak öne çıkmaktadır. En çok yayın yapan yazar, "Li Y" dir. En çok kullanılan anahtar kelimeler arasında "microgravity, space flight ve space radiation" yer almaktadır.

Sonuç: Bu çalışmanın bulguları yalnızca uzay tıbbı ve insan sağlığı ile ilgilenen araştırmacı ve uygulayıcılar için değil aynı zamanda uzay uçuşlarının astronot sağlığı üzerindeki etkileri en aza indirecek pratik uygulamalar ve gelecekteki potansiyel gelişmeler hakkında fikir edinmek isteyen herkes için değerlidir. Sonuçta bu araştırma uzay uçuşlarının astronot sağlığı üzerindeki etkilerini ve bunun uzay tıbbı alanındaki önemini çevreleyip devam eden diyaloğa katkıda bulunmakta ve bu alanda gelecekteki araştırma çalışmaları için bir yol haritası sağlayacaktır.

Anahtar kelime: Uzay Uçuşu, Uzay Tıbbı, Mikrogravite, Bibliyometrik Analiz

OPTIMIZATION OF V/III RATIO IN AlN THIN FILMS ON PATTERNED SAPPHIRE SUBSTRATES

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ABSTRACT

Aluminum nitride (AlN) thin films, which have a wide range of applications in the UV region, were grown on patterned sapphire substrates in this study using high and low V/III ratios. The effects of different V/III ratios on the structural quality, optical properties, and growth mode of the AlN films were investigated. Ammonia gas flow rates were set to 590 and 1180 sccm for low and high V/III ratios, respectively. Optical properties were analyzed using UV-Vis-NIR spectrophotometry, while surface morphology and crystal structure were characterized by scanning electron microscopy (SEM) and high-resolution X-ray diffraction (HR-XRD). The results showed that films grown with a high V/III ratio exhibited narrower full width at half maximum (FWHM) values in XRD measurements, indicating better crystal quality. These films also demonstrated higher total and diffuse reflectance, leading to smoother surface morphology and improved optical performance. In contrast, films grown with a low V/III ratio showed more pronounced lateral growth, which increased surface roughness and reduced both structural and optical quality. In single-layer samples, a high V/III ratio promoted three-dimensional (3D) growth and enhanced crystal quality. In two-layer structures, where layers with high and low V/III ratios were grown sequentially, initiating growth with high ammonia flow facilitated the formation of larger and more uniform nucleation islands, resulting in more stable crystal growth. These findings reveal that controlling the V/III ratio is critical to achieving high-quality AlN thin films, especially for optoelectronic devices requiring precise material properties.

Keywords: AlN on PSS, V/III Ratio, MOCVD, XRD, SEM, Spectrophotometer

TEMPERATURE OPTIMIZATION OF AlN THIN FILMS ON PATTERNED SAPPHIRE SUBSTRATE

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ABSTRACT

This research explores the impact of temperature modulation interfaces on the growth behavior and structural quality of aluminum nitride (AlN) thin films deposited on c-plane patterned sapphire substrates (PSS) using the Pulsed Atomic Layer Epitaxy (PALE) method. The films were grown via metal-organic vapor-phase epitaxy (MOVPE), with all growth conditions held constant except for temperature. The high and low growth temperatures were set at 1440°C and 1250°C, respectively. Three sample configurations were designed: Sample A with a high/low/high temperature sequence, Sample B with a high/low sequence, and Sample C grown entirely at the high temperature. Each sample underwent a total of 3600 growth cycles: Sample A had 1200 cycles per layer, Sample B had 1800 cycles per layer, and Sample C consisted of a single continuous layer with all 3600 cycles. Various characterization techniques, including high-resolution X-ray diffraction (HR-XRD), UV-Vis-NIR spectrophotometry, and scanning electron microscopy (SEM), were employed to analyze the samples. The results revealed that minimizing the number of temperature transition interfaces leads to improved crystal quality. Sample C, grown without any temperature modulation, exhibited the smoothest surface and the lowest dislocation densities, indicating superior structural quality. These findings underscore the importance of optimizing temperature profiles to enhance the structural and functional performance of AlN thin films for advanced applications.

Keywords: AlN on PSS, Temperature, MOCVD, XRD, SEM, Spectrophotometer

A STUDY ON DETERMINATION OF YIELD CHARACTERISTICS OF SOME DRY BEAN GENOTYPES

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ABSTRACT

In order to determine the agro-morphological characteristics of dry bean genotypes in Sivas ecological conditions, a total of 10 dry bean genotypes, including 6 registered varieties and 4 advanced dry bean lines, were used in the study conducted in the Sivas Science and Technology University Agricultural Research and Development Center in the 2024 dry bean vegetation period in a randomized block experimental design with three replications. In the conducted study, agronomic parameters such as plant height, first pod height, biological yield, number of pods per plant, number of seeds per plant, number of seeds per pod, hundred seed weight, harvest index and seed yield per plant were examined. As a result of the conducted study, it was determined that the dry bean genotypes had seed yields per plant between 20.58-95.57 g. In addition, depending on the dry bean genotypes, it was observed that the plant height was 42.98-68.22 cm, the first pod height was 13.28-26.60 cm, the biological yield was 46.22-104.35 g, the number of pods per plant was 15.00-39.00, the number of seeds per plant was 35.00-116.00, the number of seeds per pod was 3.45-4.80, the hundred-seed weight was 33.28-50.89 g and the harvest index was 42.19-59.11%. As a result; It was observed that the performance yields of the dry bean genotypes K-1044, K-1084 and A-27, which were brought to the advanced level, were higher than the other dry bean genotypes.

Keywords: Sivas, dry bean, variety, genotype, yield.

BAZI KURU FASULYE GENOTİPLERİNNİN VERİM ÖĞLERİNİNBELİRLENMESİ ÜZERİNE BİR ARAŞTIRMA

ÖZET

Sivas ekolojik koşullarında kuru fasulye genotiplerinin agro-morfolojik özelliklerinin belirlenmesi amacıyla 2024 yılı kuru fasulye vejetasyon döneminde Sivas Bilim ve Teknoloji Üniversitesi Tarımsal AR-GE Merkezinde tesadüf blokları deneme deseninde üç tekrarlamalı olarak yürütülen çalışmada 6 adet tescilli çeşit ile 4 adet ileri düzeye kadar getirilmiş kuru fasulye hattı olmak üzere toplam 10 adet kuru fasulye genotipi kullanılmıştır. Yürütülen çalışmada agronomik parametreler olan bitki boyu, ilk bakla yüksekliği, biyolojik verim, bitkide bakla sayısı, bitkide tane sayısı, baklada tane sayısı, yüz tane ağırlığı, hasat indeksi ve bitkide tane verimi özellikleri incelenmiştir. Yürütülen çalışma sonucunda kuru fasulye genotiplerinin 20.58-95.57 g arasında bitkide tane verimlerine sahip oldukları belirlenmiştir. Bunun yanında kuru fasulye genotiplerine bağlı olarak bitki boyunun 42.98-68.22 cm, ilk bakla yüksekliğinin 13.28-26.60 cm, biyolojik veriminin 46.22-104.35 g, bitkide bakla sayısının 15.00-39.00 adet, bitkide tane sayısının 35.00-116.00 adet, baklada tane sayısının 3.45-4.80 adet, yüz tane ağırlığının 33.28-50.89 g ve hasat indeksinin ise %42.19-59.11değerlerine sahip oldukları görülmüştür. Sonuç olarak; Zülbiye ve Önceler-98 kuru fasulye çeşitleri ile ileri düzeye kadar getirilmiş olan K-1044, K-1084 ve A-27 nolu kuru fasulye genotiplerinin performans verimlerinin diğer kuru fasulye genotiplerine nazaran daha yüksek olduğu görülmüştür.

Anahtar Kelimeler: Sivas, kuru fasulye, çeşit, genotip, verim.

DETERMINATION OF QUALITY CHARACTERISTICS OF SOME DRY BEAN GENOTYPES

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ABSTRACT

The research conducted in 2024 in order to reveal the quality parameters of some dry bean genotypes in Sivas ecological conditions was established in the trial plots of the Research and Development Center of Sivas Science and Technology University. In the study, 10 dry bean genotypes were used, including 4 local dry bean genotypes selected by pure line selection method and 6 dry bean varieties registered by Agricultural Research Institutes in our country. The study, which was conducted for one year, was established in a randomized block experimental design with 3 replications. During the research, data of 6 quality traits (Water Uptake Capacity (g/seed), Water Uptake Index (%), Swelling Capacity (ml/seed), Swelling Index (%), Shell Ratio (%) and Protein Ratio (%)) belonging to dry bean genotypes were revealed. According to the results of the variance analysis, statistically significant or very significant differences were determined among the dry bean genotypes in terms of all characteristics within the quality parameters considered. In the study conducted, the highest protein rate was determined in the Noyanbey 98 variety with 23.07%, while the lowest protein rate was revealed in the Yunus 90 variety with 20.62%.

Keywords: Sivas, dry bean, genotype, variety, quality, protein.

BAZI KURU FASULYE GENOTİPLERİNİN KALİTE ÖZELLİKLERİNİN ORTAYA KONULMASI

ÖZET

Bazı kuru fasulye genotiplerine ait kalite parametrelerinin Sivas ekolojik koşullarında ortaya konulması amacıyla 2024 yılında yürütülen araştırma, Sivas Bilim ve Teknoloji Üniversitesinin AR-GE Tarımsal Araştırma Merkezine ait deneme parsellerinde kurulmuştur. Çalışmada saf hat seleksiyon yöntemi ile seçilmiş 4 adet yerel kuru fasulye genotipi ile ülkemizde Tarımsal Araştırma Enstitüleri tarafından tescil ettirilmiş 6 adet kuru fasulye çeşidi olmak üzere 10 adet kuru fasulye genotipi kullanılmıştır. Bir yıl süresince yürütülen çalışma tesadüf blokları deneme deseninde 3 tekerrürlü olarak kurulmuştur. Araştırma süresince kuru fasulye genotiplerine ait 6 adet kalite özelliğinin (Su Alma Kapasitesi (g/tane), Su Alma İndeksi (%), Şişme Kapasitesi (ml/tane), Şişme İndeksi (%), Kabuk Oranı (%) ve Protein Oranı (%)) verileri ortaya konulmuştur.

Yapılan varyansa analiz sonuçlarına göre ele alınan kalite parameteleri içinde tüm özellikler bakımından kuru fasulye genotipleri arasında istatistiksel anlamda önemli yada çok önemli farklılıklar belirlenmiştir. Yürütülen çalışmada en yüksek protein oranı %23.07 ile Noyanbey 98 çeşidinde belirlenirken en düşük protein oranı ise %20.62 ile Yunus 90 çeşidinde ortaya konulmuştur.

Anahtar Kelimeler: Sivas, kuru fasulye, genotipi, çeşit, kalite, protein.

RARE EARTH ELEMENTS: INDUSTRIAL USES AND RESERVES

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ABSTRACT

Rare earth elements (REEs) are a group of 17 elements including 15 silvery-white metals called lanthanides or lanthanoids and scandium and yttrium. Rare earth elements are classified as heavy (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) and light (Sc, La, Ce, Pr, Nd, Pm, and Sm). A rare earth mineral contains one or more rare earth elements as the main metal constituent. Rare earth minerals are commonly found in pegmatites or carbonatite intrusions with alkaline to percaline igneous rocks. Important ore minerals include gadolinite, monazite, xenotime, bastnasite, zircon, apatite, titanite, fluorite, and uraninite. Although rare earth elements are technically relatively abundant throughout the Earth's crust (cerium is the 25th most abundant element at 68 ppm, more abundant than copper), in practice they are finely distributed among these trace impurities. The countries with the largest rare earth mineral reserves are China – 44 million metric tonnes (mt; 1mt is equal to 1,000 kilograms), followed by other countries (Brazil – 21 mt, India – 6.9 mt, Australia – 5.7 mt, Russia – 3.8 million mt, Vietnam – 3.5 million mt, ABD – 1.9 million mt, Greenland – 1.5 million mt, Tanzania – 890,000 mt, South Africa – 860,000 mt, Canada – 830,000 mt, Thailand – 4,500 mt). Consumer electronics, electric vehicles (EVs), aircraft They are used in a wide range of products, including engines, medical equipment, petroleum refining, and military applications such as magnets, missiles and radar systems. China accounts for about 70% of global mineral production and 90% of processed and permanent magnet output. Beijing sets quotas on output, smelting and separation, which are closely watched as a barometer of global supply. Today, Ukraine has reserves of rare earth elements (REEs) and precious minerals, including lanthanum, cerium and neodymium, which are essential for high-tech applications such as electronics, defense, aerospace and renewable energy. Ukraine is believed to have about 5% of the world's rare earth reserves. The latest data in our country indicate that there is a reserve potential of approximately 600 mt.

Keywords: Energy, Natural geologic resources, High-tech applications, Strategic mineral, REEs

NADİR TOPRAK ELEMENTLERİ: ENDÜSTRİYEL KULLANIMLARI VE REZERVLER

ÖZET

Nadir toprak elementleri (REEs), lantanitler veya lantanoidler olarak adlandırılan 15 gümüş-beyaz metal ile skandiyum ve itriyumu da içeren 17 elementten oluşan bir gruptur. Nadir toprak elementleri ağır (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb ve Lu) ve hafif (Sc, La, Ce, Pr, Nd, Pm ve Sm) olarak sınıflandırılır. Nadir toprak mineral, ana metal bileşenler olarak bir veya daha fazla nadir toprak elemneti içerir. Nadir toprak mineralleri genellikle pegmatitlerde veya karbonatit sokulumlarında alkalin ile perkalin magmatik kayalarla birlikte bulunur. Önemli cevher mineralleri gadolinit, monazit, ksenotim, bastnasit, zirkon, apatit, titanit, florit ve uraninit olarak bilinir. Nadir toprak elementleri teknik olarak Dünya'nın tüm kabuğunda nispeten bol miktarda bulunsa da (seryum 68 ppm ile 25. en bol bulunan elementtir ve bakırdan daha bol miktarda bulunur), pratikte bu eser miktardaki safsızlıklar arasında ince bir şekilde dağılmıştır, En büyük nadir toprak mineral rezervlerine sahip ülkeler başta China – 44 million metric tonnes (mt; 1mt is equal to 1,000 kilogrammes) olmak üzere, diğer ülkeler (Brezilya – 21 mt, Hindistan – 6.9 mt, Avustralya– 5.7 mt, Rusya – 3.8 million mt, Vietnam – 3.5 million mt, ABD – 1.9 million mt, Grönland – 1.5 million mt, Tanzanya– 890,000mt, Güney Afrika – 860,000mt, Kanada – 830,000mt, Tayland – 4,500mt) olarak bilinir. Tüketici elektroniği, elektrikli araçlar (EV'ler), uçak motorları, tıbbi ekipmanlar, petrol rafinasyonu, mıknatıs, füzeler, cam ve radar sistemleri gibi askeri uygulamalar dahil olmak üzere çok çeşitli ürünlerde kullanılırlar. Çin, küresel maden üretiminin yaklaşık %70'ini ve işlenmiş ve kalıcı mıknatıs çıktısının %90'ını oluşturmaktadır. Pekin, küresel arzın bir barometresi olarak yakından izlenen çıktı, eritme ve ayırma konusunda kotalar koymaktadır. Bugün Ukrayna lantan, seryum ve neodimyum gibi elektronik, savunma, havacılık ve yenilenebilir enerji gibi yüksek teknoloji uygulamaları için gerekli olan 17 metalik mineralden oluşan nadir toprak elementleri (REEs) ve değerli mineral rezervlerine sahiptir. Ukrayna'nın dünyanın nadir toprak unsurları rezervlerinin yaklaşık % 5'ine sahip olduğuna inanılıyor. Ülkemizde son veriler yaklaşık 600 mt civarında bir rezerv potansiyeli olduğu belirtiliyor.

Anahtar kelimeler: Doğal jeolojik kaynaklar, Enerji, Stratejik mineral, REEs, Yüksek teknoloji ürünleri

DESIGN OF A CAVITATING INJECTOR FOR AEROSPACE ENGINES AND PERFORMANCE ANALYSIS IN A MICROJET COMBUSTION CHAMBER

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ABSTRACT

One of the most critical parts of the gas turbine combustion chamber is the injectors that perform fuel atomization. The task of the injectors is to separate the fuel into as small as possible particles in the form of a spray. Because as the atomized particle size decreases, more efficient combustion and lower emission values are obtained. Therefore, improving injector designs is of great importance not only in terms of fuel efficiency and energy production, but also in minimizing environmental effects. There are many types of injectors that perform atomization, discussed in the literature. Injectors that atomize the fuel based on the mechanical vortex principle are used in large jet engine combustion chambers. In microjet combustion chambers, where weight saving is important, cavitation fuel injectors are preferred due to the simplicity of the system and low costs. Such injectors provide atomization by dynamically collapsing the vapor bubbles in the fuel and reach very fine droplet sizes without the need for complex internal geometries, unlike mechanical vortex injectors. In this study, the spray characteristics of a cavitation fuel injector will be analysed using experimental and numerical methods together. For this purpose, nozzle geometries will be determined and manufactured in a way that will create cavitation. Then, the manufactured injector will be adapted to a test setup with adjustable fuel pressure and flow rate. Droplet size distribution will be determined by the laser diffraction method using the Malvern Spray Analyzer device, and droplet breakup dynamics due to cavitation will be observed in detail with a high-speed camera. The effects of different injection pressures and different types of fuels on atomization efficiency, spray stability, and possible injector erosion will be analysed. In addition, spray characteristics such as droplet size distribution, spray cone angle, and penetration length will be measured and verified by numerical simulations. Finally, the optimized injector will be integrated into a microjet gas turbine and combustion performance will be evaluated in terms of parameters such as fuel-air mixture, combustion efficiency and pressure loss with CFD-based analyses.

Keywords: Injector, Nozzle, Cavitation, Atomization, CFD

HAVACILIK MOTORLARINDA KAVİTASYONLU ENJEKTÖR TASARIMI VE MİKROJET YANMA ODASINDAKİ PERFORMANS ANALİZİ

ÖZET

Gaz türbinleri yanma odasının en kritik parçalarından biri yakıt atomizasyonu gerçekleştiren enjektörlerdir. Enjektörlerin görevi yakıtı sprey halinde mümkün olduğunca küçük parçalara ayırmaktır. Çünkü atomize edilen parça boyutu küçüldükçe daha verimli bir yanma ve daha düşük emisyon değerleri elde edilmiş olur. Bu nedenle, enjektör tasarımlarının iyileştirilmesi, sadece yakıt verimliliği ve enerji üretimi açısından değil, aynı zamanda çevresel etkilerin minimize edilmesi için de büyük önem taşır. Literatürde atomizasyonu gerçekleştiren birçok enjektör çeşidi vardır. Büyük jet motor yanma odalarında mekanik girdap prensibine dayanarak yakıtı atomize eden enjektörler kullanılmaktadır. Ağırlık tasarrufunun önemli olduğu mikrojet yanma odalarında ise sisteminin basitliği ve düşük maliyetleri açısından kavitasyonlu yakıt enjektörleri tercih edilmektedir. Bu tür enjektörler, yakıt içerisindeki buhar kabarcıklarının dinamik olarak çökmesi ile atomizasyonu sağlayıp çok ince damlacık boyutlarına mekanik girdaplı enjektörlerin aksine karmaşık iç geometrilere ihtiyaç duymadan ulaşırlar. Bu çalışmada deneysel ve sayısal yöntemler birlikte kullanılarak kavitasyonlu bir yakıt enjektörünün püskürtme karakteristikleri analiz edilecektir. Bunun için nozul geometrileri kavitasyon oluşturacak şekilde belirlenip üretilecektir. Daha sonra üretilen enjektör, yakıt basıncı ve debisi ayarlanabilir bir test düzeneğine uyarlanacaktır. Malvern Spray Analyzer cihazı ile damlacık boyutu dağılımı lazer kırınım yöntemiyle belirlenecek, yüksek hızlı bir kamera ile kavitasyona bağlı damlacık parçalanma dinamikleri ayrıntılı biçimde gözlemlenecektir. Farklı enjeksiyon basıncının ve farklı tür yakıtların; atomizasyon verimliliği, sprey stabilitesi ve olası enjektör erozyonuna etkileri analiz edilecektir. Ayrıca; damlacık boyutu dağılımı, sprey koni açısı ve penetrasyon uzunluğu gibi püskürtme karakteristikleri, sayısal simülasyonlar ile yapılacak ve doğrulanacaktır. Son olarak optimize edilen enjektör bir mikrojet gaz türbinine entegre edilerek yanma performansı CFD tabanlı analizlerle yakıt-hava karışımı, yanma verimi ve basınç kaybı gibi parametreler açısından değerlendirilecektir.

Anahtar Kelimeler: Enjektör, Nozul, Kavitasyon, Atomizasyon, CFD

ENHANCING THE AERODYNAMIC PERFORMANCE OF THICK AIRFOILS VIA FLEXIBLE MEMBRANE AND GURNEY FLAP APPLICATIONS

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ABSTRACT

The aerodynamic efficiency of wind turbine blades is crucial for improving energy output, especially in small and medium-scale turbines operating under low Reynolds number conditions. The present study examines novel passive flow control methods intended at enhancing the performance of thick airfoils typically used near the root region of wind turbine blades. Employing the DU00-W2-350 airfoil profile, the study investigates the impact of different flexible membrane materials (Latex Rubber, EPDM, and Neoprene) applied to both suction and pressure surfaces, as well as a flexible Gurney flap integrated into the trailing edge. Unlike traditional rigid control devices, these flexible membranes passively adapt to flow conditions, enabling dynamic suppression of boundary layer separation and vibration. A combination of high-fidelity Computational Fluid Dynamics (CFD) simulations and subsonic wind tunnel experiments is employed to analyse aerodynamic behaviour across a range of Reynolds numbers (100,000–250,000) and angles of attack (0°–25°). The study also visualises flow separation and laminar separation bubbles using smoke-wire techniques. The anticipated outcome is a significant increase in lift-to-drag ratio and overall aerodynamic efficiency, particularly in transitional flow regimes. By filling a critical gap in the literature—specifically, the use of flexible materials on pressure surfaces and the synergistic effects of multi-material, multi-region configurations—this research offers a pioneering perspective for optimizing blade performance in real-world wind energy applications. The findings aim to contribute not only to academic knowledge but also to future full-scale wind turbine design strategies and national energy policies.

Keywords: Flexible membrane, Gurney flap, Airfoils, Flow separation control, CFD

LAND DEGRADATION IN RANGELANDS: CAUSES, INDICATORS, AND MANAGEMENT STRATEGIES

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ABSTRACT

Rangelands are ecosystems that cover 31.2% of the world's terrestrial area and 37.8% of Turkey's agricultural lands, playing a vital role for rural communities. These semi-natural areas provide a wide range of ecosystem services, including food, fiber, water, recreation, and minerals, as well as essential roughage for livestock, making them crucial for livelihoods worldwide, particularly in developing countries. However, competition in land use, extreme climate events, socioeconomic changes, and excessive or improper grazing have led to rangelands degradation in many regions.

Studies indicate that overgrazing reduces soil aggregate stability by 30-50% and significantly increases erosion risk. The effects of climate change, particularly drought and rising temperatures, accelerate degradation by reducing vegetation regeneration capacity. Woody plant invasion decreases forage productivity by up to 60%, leading to both ecological and economic losses. This review concludes that on-site measurements—such as soil aggregate stability, bare soil ratio, and vegetation composition—along with remote sensing technologies (NDVI, MODIS), are critical for understanding the spatial and temporal distribution of degradation. Among the proposed strategies for sustainable rangeland management, controlled grazing systems, woody plant control, and early warning systems stand out. Community-based management models, integrating local knowledge and scientific data, yield more effective results. Additionally, new policies are recommended to revise rangeland rights and grazing regulations.

Given our dependence on rangelands, the degradation of these resources is believed to have large-scale impacts. This paper examines the primary causes of rangeland degradation, discusses indicators for identifying degradation, and evaluates methods for assessing the degree of degradation in rangeland ecosystems. Furthermore, options and considerations for restoring degraded rangelands are presented, along with forward-looking approaches for monitoring and evaluating rangeland degradation.

Keywords: Land Degradation, Monitoring, Rangeland, Restoration, Management Strategies

MERALARDA ARAZİ BOZULMASI: NEDENLERİ, GÖSTERGELERİ VE YÖNETİM STRATEJİLERİ

ÖZET

Meralar, dünya karasal alanının %31,2'sini, Türkiye tarım alanlarının %37,8'ini kaplayan ve kırsal topluluklar için hayati öneme sahip olan ekosistemlerdir. Bu yarı doğal alanlar gıda, lif, su, rekreasyon, maden gibi çok çeşitli ekosistem hizmetleri ve çiftlik hayvanlarının beslenmesi için gereken temel kaba yemi sağlayarak dünya genelinde, özellikle gelişmekte olan ülkelerde insanların geçiminde önemli rol oynamaktadır. Ancak arazi kullanımındaki rekabet, ekstrem iklim olayları, sosyoekonomik değişimler, aşırı ve usulüne uygun olmayan otlatma birçok bölgede meraların bozulmasına yol açmaktadır.

Yürütülen çalışmalar, aşırı otlatmanın toprak agregat stabilitesini %30-50 oranında azalttığını ve erozyon riskini önemli ölçüde artırdığını göstermektedir. İklim değişikliğinin etkileri, özellikle kuraklık ve sıcaklık artışları, bitki örtüsünün yenilenme kapasitesini düşürerek bozulma sürecini hızlandırmaktadır. Odunsu bitki istilası ise ot verimliliğini %60'a varan oranlarda azaltarak hem ekolojik hem de ekonomik kayıplara yol açmaktadır. İncelemede, toprak agregat stabilitesi, çıplak toprak oranı ve bitki örtüsü kompozisyonu gibi yerinde ölçümlerin yanı sıra, uzaktan algılama teknolojilerinin (NDVI, MODIS) bozulmanın mekânsal ve zamansal dağılımını anlamada kritik öneme sahip olduğu kanaatine varılmıştır. Sürdürülebilir mera yönetimi için önerilen stratejiler arasında kontrollü otlatma sistemleri, odunsu bitki kontrolü ve erken uyarı sistemleri öne çıkmaktadır. Topluluk tabanlı yönetim modelleri, yerel bilgi ve bilimsel verilerin entegrasyonunu sağlayarak, daha etkili sonuçlar vermektedir. Ayrıca, düzenlenen yeni politikalar ile mera hakları ve otlatma düzenlemelerinin gözden geçirilmesi önerilmektedir.

Meralara olan bağımlılığımız göz önüne alındığında, bu kaynaklardaki bozulmanın geniş ölçekli etkilere neden olduğu düşünülmektedir. Bu bildiride, mera bozulmasının başlıca nedenleri incelenmekte; bozulmayı belirlemek için kullanılabilecek göstergeler ile mera ekosistemlerindeki bozulma derecesini değerlendirme yöntemleri tartışılmaktadır. Ayrıca, bozulmuş meraların restore edilmesine yönelik seçenekler ve dikkat edilmesi gereken hususlar sunulmakta, mera bozulmasının izlenmesi ve değerlendirilmesinde geleceğe dönük yaklaşımlar ele alınmaktadır.

Anahtar Kelimeler: Arazi Bozulması, İzleme, Mera, Restorasyon, Yönetim Stratejileri

GRASSLAND BIODIVERSITY: CURRENT STATUS AND CHALLENGES

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ABSTRACT

Grassland biodiversity is a complex phenomenon that encompasses multiple interconnected components, including the diversity of organisms, genetic variation among these organisms, the communities they form, ecosystem structures, and landscape patterns. The ecological functions and diversity offered by biodiversity are critically important not only in terms of ecosystem services but also from ethical, aesthetic, and economic perspectives. Grasslands, often located in areas unsuitable for agriculture due to irregular and low precipitation, rocky formations, poor drainage, and extreme temperature conditions, provide forage and water for freely roaming wild and domestic animals, as well as natural resources such as timber and minerals. These areas, typically characterized by shallow soils and slow nutrient cycling, are among the most ecologically fragile environments. Grassland biodiversity is threatened by a range of factors, including habitat loss and fragmentation, invasive species pressure, climate change, wildfires, prolonged drought, overgrazing, lack of interdisciplinary coordination, and insufficient implementation capacity. Despite these challenges, various strategies such as community-based management systems, participatory planning approaches, invasive species control, grassland restoration, integrated and sustainable management models, and the preservation of local knowledge systems offer significant opportunities for the conservation and enhancement of grassland biodiversity. The main objective of this review is to analyze the existing body of literature on grassland biodiversity, to assess the current status, identify the main challenges, and evaluate potential opportunities in this field. The findings indicate a significant decline in grassland biodiversity, highlighting the urgent need for the development of conservation-focused grassland management strategies.

Keywords: Biodiversity conservation, rangelands, sustainability, ecosystem

MERA BİYOÇEŞİTLİLİĞİ: MEVCUT DURUM VE KARŞILAŞILAN GÜÇLÜKLER

ÖZET

Mera biyoçeşitliliği; organizmaların çeşitliliği, bu organizmalar arasındaki genetik varyasyonlar ile bunların oluşturduğu topluluklar, ekosistem yapıları ve peyzaj desenleri gibi çok katmanlı bileşenleri içeren karmaşık bir olgudur. Biyoçeşitliliğin sunduğu ekolojik işlevler ve çeşitlilik, yalnızca ekosistem hizmetleri açısından değil, aynı zamanda etik, estetik ve ekonomik değerler bakımından da son derece önemlidir. Tarıma elverişsiz olan, düzensiz ve düşük yağış alan, kayalık yapılar içeren, zayıf drenaja ve ekstrem sıcaklık koşullarına sahip alanlarda yer alan meralar; serbest dolaşan yabani ve evcil hayvanlar için yem ve su kaynağı olmanın yanı sıra, kereste ve maden gibi doğal kaynakları da sunmaktadır. Genellikle sığ topraklı ve besin döngüsü yavaş olan bu alanlar, ekolojik kırılganlık açısından hassas bölgeler arasında yer almaktadır. Mera ekosistemlerinin biyoçeşitliliği, habitat kaybı ve parçalanması, istilacı türlerin baskısı, iklim değişikliği, yangınlar, uzun süreli kuraklık, aşırı otlatma, disiplinler arası eşgüdüm eksikliği ve yetersiz uygulama kapasiteleri gibi birçok tehditle karşı karşıya kalmaktadır. Bu zorluklara rağmen; topluluk temelli yönetim sistemleri, katılımcı planlama yaklaşımları, istilacı türlerin kontrolü, mera restorasyonu, entegre ve sürdürülebilir yönetim modelleri, yerel bilgi sistemlerinin korunması gibi uygulamalar, mera biyoçeşitliliğinin korunması ve iyileştirilmesi açısından önemli fırsatlar sunmaktadır. Bu derlemenin temel amacı, mera biyoçeşitliliğine ilişkin literatürde yer alan mevcut bilgi birikimini analiz ederek, güncel durumu ortaya koymak ve karşılaşılan sorunlar ile bu alandaki potansiyel fırsatları değerlendirmektir. Çalışma sonucunda, mera biyoçeşitliliğinde ciddi bir gerilemenin söz konusu olduğu ve bu durumun, koruma odaklı mera yönetim stratejilerinin acilen geliştirilmesini gerekli kıldığı sonucuna varılmıştır.

Anahtar Kelimeler: Biyoçeşitliliğin korunması, meralar, sürdürülebilirlik, ekosistem

GROWTH OF COTTON CULTIVARS IN RESPONSE TO MULTIWALLED CARBON NANOTUBES

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ABSTRACT

Cotton is a perennial crop that is commercially cultivated in many parts of the world. Cotton by-products have provided producers with additional value, mainly in livestock feed supplements and soil amendments. However, the quality of cotton bioproducts is significant for sustainable cotton production. The present research investigates the effects of carbon nanotubes (CNTs) on in vitro germination and growth rate of three commercial cultivars (Progen Ad, ST-468, and Esperia) of cotton in Turkey. The seedlings were sterilized with 0.1% HgCl2 and cultured on MS medium enriched with different CNT concentrations (0, 40, 80, 160, and 240 mg) on cotton seed germination, growth parameters, and biomass. The results indicated that lower CNTs concentrations (40–160 mg) enhanced germination rates, root-to-shoot biomass ratios, and stimulation in comparison to the control. However, the highest CNTs concentration (240 mg) exhibited inhibiting impacts on the studied parameters, illustrating the significance of appropriate dosage. Esperia. exhibited the substantial germination rate, whereas ST-468 demonstrated the overall performance with significant germination and improved all growth parameters. ST-468 had the maximum germination rate, whereas Progen Ad exhibited the lowest percentage. These findings support that the growth parameters can be influenced by different carbon sources or experimental conditions. The research provides new findings on the function of carbon-based nanomaterials to stimulate plant development.

Keywords: Cotton, Carbon nanotubes, germination,

VALIDATION AND PREDICTION OF IN VITRO GERMINATION AND GROWTH OF COWPEA (*VIGNA UNGUICULATA L.*) CULTIVARS

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ABSTRACT

Cowpea (*Vigna unguiculata*) is an important legume with immense potential to address global food security challenges due to its nutritional and agricultural benefits. Enhancing cowpea's essential micronutrient content through biofortification offers a sustainable approach to combat malnutrition, particularly in regions heavily reliant on this crop. This innovative strategy not only improves nutrient bioavailability in diets but also enhances soil health and agricultural productivity. By integrating biofortification techniques with nanotechnology, specifically using carbon nanotubes (CNTs), this study explores promising pathways for improving cowpea's nutritional value and overall yield, thereby supporting healthier diets and sustainable farming practices for a growing global population. The seedlings were sterilized with 70% alcohol and cultured on MS medium enriched with different CNTs concentrations including 0, 50, 75, 100, 125, and 150 mg/L six treatment and each treatment have eight replications. The observed parameters were seed germination, growth parameters, and biomass of two cowpea cultivars. The results revealed significant differences in cowpea growth and germination between two cultivars Karagoz and Bodrum. The average germination percentage for Karagoz recorded significantly (79.02%) more compared to Bodrum (60.73%). Variability in germination was slightly greater in Bodrum, as reflected by a standard deviation of (12.32) compared to (10.20) in Karagoz. In terms of fresh weight, Karagoz demonstrated significant results, with an average of (93.36) and a maximum of (217.31) while Bodrum averaged (40.64) with a maximum of (110.12) The dry weight of Karagoz (0.73g) was significantly more than Bodrum (0.51g), showing improved growing performance of Karagoz. The present research indicates that biofortification with CNTs positively improves cowpea growth, particularly in Karagoz by enhancing biomass production. CNTs improved nutrient absorption and water retention, promoting enhanced plant development. Variations in germination and biomass between the cultivars may result from differences in experimental conditions, such as nutrient availability or CNT concentrations. The present study highlights the potential of combining biofortification and nanotechnology to sustainably address global food security challenges.

Keywords. Biofortification, Nanotechnology, Germination, Biomass Production, Nutrient Absorption, Growth Parameters

INVESTIGATION OF THE EFFECTS OF SOME HERBICIDES TREATMENTS ON YIELD AGAINST COMMON WEEDS IN SUGAR BEET PLANTING AREAS OF BAYBURT PROVINCE

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ABSTRACT

It was carried out to evaluate the effectiveness of different herbicides applied against weeds in sugar beet cultivation areas of Bayburt province and the effects of these applications on sugar beet yield and quality parameters. In this study, a total of 40 plots with 5 replicate control plots of 20 m² were established in Tomlacık village of Bayburt province in 2024. In these plots, herbicides with different active ingredients and physical control methods were applied and their effects on sugar beet development, yield and sugar content were evaluated comparatively. In chemical control, herbicide mixtures containing especially 400 g/l Metamitron + 55 g/l Ethofumesate + 35 g/l Phenmedipham and 350 g/l Metamitron + 150 g/l Ethofumesate have shown high effectiveness against the mentioned weed species. According to the data obtained from the plants in the plots where these applications were made, a visible increase was obtained in the growth of the sugar beet plant and the sugar content within it. In the plots where no application was made, the weed density was high and a negative effect was observed on the development and sugar content of the beets. The most common weed species in the sugar beet planting areas in Bayburt province were determined as wild mustard (*Sinapis arvensis* L.), siren (*Chenopodium album* L.) and red-rooted foxtail (*Amaranthus retroflexus* L.). In the applications, physical control has emerged as the most effective method in controlling weeds. In chemical control, mixtures containing 400 g/l Metamitron + 55 g/l Ethofumesate + 35 g/l Phenmedipham and 350 g/l Metamitron + 150 g/l Ethofumesate were found to be more effective. These methods supported the development of sugar beet by reducing weed density and directly contributed to the increase in yield.

Keywords: Sugar beet, weed, herbicide, physical control, yield, Bayburt

EVALUATION OF DROUGHT STRESS IN PLANT MELISSA (*Melissa officinalis* L.) UNDER *IN VITRO* CONDITIONS

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ABSTRACT

In this study was conducted to investigate the effects of drought stress on the morphological development of melissa (*Melissa officinalis* L.) under *in vitro* conditions. The study was carried out in the Tissue Culture Laboratory of Prof. Dr. Saadet BÜYÜKALACA, Department of Horticulture, Faculty of Agriculture, Çukurova University. Polyethylene glycol 6000 (PEG-6000) was added to Murashige and Skoog (MS) basal nutrient medium at 0% (control), 2%, 4% and 6% to simulate drought stress. PEG decreases the osmotic potential, limiting the biological accessibility of water in the medium and thus induces drought stress in vitro. In the experiment, basic morphological and physiological parameters such as germination rate (%), stem length (mm), root length (mm), stem wet and dry weight (g) and root wet and dry weight (g) were measured to evaluate the effects of PEG treatments on the in vitro development of lemon balm plants. The data obtained during the study revealed that plant growth was gradually retarded with the increase in PEG concentration. In this context, artificial drought conditions created *in vitro* by PEG treatments provide an effective model system for evaluating the drought responses of medicinal-aromatic plants such as melissa.

Keywords: Abiotic stress, Drought, Melissa, *In vitro*

MELİSA (*Melissa officinalis* L.) BİTKİSİNİN *İN VİTRO* KOŞULLARDA KURAKLIK STRESİNİN BELİRLENMESİ

ÖZET

Bu çalışma, kuraklık stresinin *in vitro* koşullarda melisa (*Melissa officinalis* L.) bitkisinin morfolojik gelişimi üzerindeki etkilerini araştırmak amacıyla yürütülmüştür. Araştırma, Çukurova Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü Prof. Dr. Saadet BÜYÜKALACA Doku Kültürü Laboratuvarı'nda gerçekleştirilmiştir. Kuraklık stresini simüle etmek amacıyla Murashige ve Skoog (MS) bazal besin ortamına %0 (kontrol), %2, %4 ve %6 oranlarında polietilen glikol 6000 (PEG-6000) ilave edilmiştir. PEG, osmotik potansiyeli düşürerek ortamdaki suyun biyolojik erişilebilirliğini sınırlandırmakta ve bu sayede *in vitro* kuraklık stresini oluşturmaktadır. Denemede, PEG uygulamalarının melisa bitkisinin in vitro gelişimi üzerindeki etkilerini değerlendirmek üzere çimlenme oranı (%), gövde uzunluğu (mm), kök uzunluğu (mm), gövde yaş ve kuru ağırlığı (g) ile kök yaş ve kuru ağırlığı (g) gibi temel morfolojik ve fizyolojik parametreler ölçülmüştür. Araştırma süresince elde edilen veriler, PEG konsantrasyonundaki artışa bağlı olarak bitki gelişiminin kademeli biçimde gerilediğini ortaya koymuştur. Bu bağlamda, PEG uygulamaları ile *in vitro* ortamda oluşturulan yapay kuraklık koşulları, melisa gibi tıbbi-aromatik bitkilerin kuraklığa karşı yanıtlarını değerlendirmede etkili bir model sistemi sunmaktadır.

Anahtar kelimeler: Abiyotik stres, Kuraklık, Melisa, *İn vitro*

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DETERMINATION OF DROUGHT STRESS IN SUMMER SQUASH VARIETIES UNDER *IN VITRO* CONDITIONS

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ABSTRACT

In this study was carried out to determine the effects of different drought stress levels on the morphological development of summer squash cultivars under *in vitro* tissue culture conditions. Drought stress was induced by adding different concentrations (0, 2, 4, 6%) of polyethylene glycol (PEG-6000) to MS medium. The research was conducted in the tissue culture laboratory of Prof. Dr. Saadet BÜYÜKALACA, Department of Horticulture, Faculty of Agriculture, Çukurova University. Morphological characteristics such as germination rate (%), stem wet and dry weight (g), root wet and dry weight (g), stem and root length (mm) of the plants exposed to different PEG levels were evaluated. The results revealed that summer squash cultivars showed different tolerances to drought stress under *in vitro* conditions and PEG-induced water stress was an important factor limiting plant growth.

Keywords: Abiotic stress, Drought, Squash, *In vitro*

YAZLIK KABAK ÇEŞİTLERİNİN *İN VİTRO* KOŞULLARDA KURAKLIK STRESİNİN BELİRLENMESİ

ÖZET

Bu çalışma, *in vitro* doku kültürü koşullarında farklı kuraklık stres düzeylerinin yazlık kabak çeşitlerinin morfolojik gelişimi üzerindeki etkilerini belirlemek amacıyla yürütülmüştür. Kuraklık stresi, MS besin ortamına farklı konsantrasyonlarda (%0, 2, 4, 6) polietilen glikol (PEG-6000) eklenerek oluşturulmuştur. Araştırma Çukurova Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü Prof. Dr. Saadet BÜYÜKALACA doku kültürü laboratuvarında yürütülmüştür. Denemede farklı PEG düzeylerine maruz bırakılan bitkilerin çimlenme oranı (%), gövde yaş ve kuru ağırlığı (g), kök yaş ve kuru ağırlığı (g), gövde ve kök uzunlukları (mm) gibi morfolojik özellikleri değerlendirilmiştir. Sonuçlar, yazlık kabak çeşitlerinin *in vitro* koşullarda kuraklık stresine farklı toleranslar gösterdiğini ve PEG kaynaklı su stresinin bitki gelişimini sınırlayıcı önemli bir etken olduğunu ortaya koymuştur.

Anahtar kelimeler: Abiyotik stres, Kuraklık, Kabak, *İn vitro*

TURBULENCE AND VISCOUS EFFECTS IN SMALL SOLID ROCKET MOTORS

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ABSTRACT

This study investigates the performance of a small solid propellant rocket motor using double-base propellant through computational fluid dynamics (CFD) simulations, considering the effects of turbulence and viscous flow dynamics. The analytical methods rely on one-dimensional fluid flow equations using mass, momentum, and energy conservation. The CFD approach models the internal flow field by treating the burning propellant surface as a mass inflow boundary, where injected gas properties are derived from equilibrium calculations using NASA CEA software. The simulations reveal significant differences between analytical predictions and CFD results, particularly in chamber pressure, exhaust velocity, and specific impulse. While the analytical method overestimates performance by neglecting flow losses due to viscosity and turbulence, the CFD analysis captures the impact of turbulence-induced mixing, viscous boundary layer development, and nozzle divergence inefficiencies due to wave losses.

Key findings indicate that the CFD-predicted chamber pressure is **4–6% lower** than the analytical value due to unresolved flow recirculation and pressure drops. Similarly, the exhaust velocity and specific impulse show a **4–5% reduction** in the CFD results, attributed to viscous dissipation and incomplete conversion of thermal energy to kinetic energy in the nozzle. These deviations highlight the limitations of the idealized analytical model. The study demonstrates that CFD provides a more accurate performance assessment, enabling better optimization of motor design parameters such as grain geometry and nozzle contour. While the decoupled combustion model simplifies the analysis, the results remain valuable for initial design phases, offering insights into real-world performance losses that analytical methods cannot predict. This work underscores the importance of incorporating high-fidelity flow simulations in solid fuel rocket motor development.

Keywords: Solid rocket motor, Propulsion, CFD, Retro Rocket

BALSA CORE COMPOSITE SANDWICH PANEL CONTAINING PEG 400

PEG 400 İHTİVA EDEN BALSA ÇEKİRDEKLİ KOMPOSİT SANDVİÇ PANEL

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ABSTRACT

Sandwich composites are widely used multilayer structural elements in various applications such as factories, workshops, hangars, cold storage rooms, and prefabricated buildings. Their advantages include easy and fast installation, high thermal and acoustic insulation, lightweight structure, and high mechanical strength. A typical sandwich composite consists of three main layers: outer face sheet, core material, and inner face sheet.

In this study, balsa wood was used as the core material, and the composite was manufactured by coating the structure with fiberglass and UV resin. As an innovative approach, the balsa core was impregnated with polyethylene glycol 400 (PEG 400), a phase change material (PCM). Prior to the impregnation process, delignification was applied to the balsa wood to enhance its porosity, thereby increasing its PCM absorption capacity. This process significantly improved the PCM loading efficiency.

Phase change materials are specialized substances used for thermal energy storage. During the phase change process, PCMs store energy in the form of latent heat as they absorb or release thermal energy. Desired properties of PCMs include high latent heat capacity, operation at a constant temperature, reusability, and environmental friendliness.

As a result, PEG 400-impregnated balsa-core sandwich composites reinforced with fiberglass were successfully produced. These structures exhibit promising characteristics in terms of both thermal energy storage potential and mechanical performance, offering a novel and functional solution for energy-efficient building components.

Keywords: Phase change materials, balsa, sandwich composite, glass fiber

A PILOT STUDY ON THE FEASIBILITY OF USING CHATBOTS IN MEDICAL EDUCATION THROUGH COMMITTEE QUESTIONS

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ABSTRACT

Medical education continues to train physicians by increasing its accumulation for centuries. In this process, various tools have been used in medical education and innovations that are still emerging can contribute to medical education. Artificial intelligence, the most up-to-date progress of our age, has also started to be included in medical education. Our study aims to investigate the usability of artificial intelligence in medical education. Chatbots operating on large language models have become widespread with well-known brand names. ChatGPT, Copilot, Grok, 3 prominent brands were included in our study. In our study, semester 2 from the intermediate classes in the faculty of medicine was preferred as a pilot. In one year, 534 questions from 7 disciplines were asked in term 2 committees. These questions were asked to chatbots that are ready to use with the most up-to-date versions for free. Copilot provided the most successful answers with an accuracy rate of 78.8%, while Grok also achieved high success with 77.7%. ChatGPT was the most error-prone chatbot with a rate of 71.7%. In terms of accuracy per course, Copilot was the most successful in histology and embryology, medical physiology, medical pathology and microbiology courses, while Grok was the most successful in anatomy, biophysics and medical pharmacology courses. The percentage of success of chatbots varies according to the field in which they are developed. If an artificial intelligence model chatbot trained for medical education is produced, it will enable us to see almost 100% successful results.

Keywords: chatbot, chatgpt, copilot, grok, medical education.

KOMİTE SORULARI ÜZERİNDEN TIP EĞİTİMİNDE CHATBOTLARIN KULLANILABİLİRLİĞİ ÜZERİNE PİLOT ARAŞTIRMA

ÖZET

Tıp eğitimi yüz yıllardır birikimini artırarak hekim yetiştirmeye devam etmektedir. Bu süreçte çeşitli araçlar tıp eğitiminde kullanılmış olup halen çıkan yenilikler de tıp eğitimine katkı sağlayabilmektedir. Çağımızın en güncel ilerlemesi yapay zeka da tıp eğitimine dahil olmaya başlamıştır. Çalışmamız yapay zekanın tıp eğitiminde kullanılabilirliğini araştırmayı amaçlamıştır. Büyük dil modelleri üzerinden faaliyet gösteren chatbotlar bilindik marka isimleriyle yaygınlaşmıştır. ChatGPT, Copilot, Grok olarak öne çıkan 3 marka çalışmamıza dahil edilmiştir. Çalışmamızda pilot olarak tıp fakültesinde ara sınıflardan dönem 2 tercih edilmiştir. Bir yılda dönem 2 komitelerinde 7 bilim dalından 534 soru sorulmuş. Bu sorular ücretsiz olarak en güncel sürümleriyle kullanıma hazır olan chatbotlara sorulmuştur. En başarılı yanıtları %78.8 doğruluk oranıyla Copilot sağlamışken, %77.7 ile Grok da yüksek başarı elde etmiştir. ChatGPT ise %71.7 oranıyla aralarında yanlışa en meyilli olan chatbottur. Ders başına doğruluk açısından değerlendirildiğinde histoloji ve embriyoloji, tıbbi fizyoloji, tıbbi patoloji ve mikrobiyoloji derslerinde Copilot, anatomi, biyofizik, tıbbi farmakoloji derslerinde Grok en başarılıdır. Chatbotlar geliştirildikleri alana göre başarılı olma yüzdeleri değişmektedir. Eğer tıp eğitimi için eğitilmiş yapay zeka modeli chatbot üretilirse neredeyse %100'e varacak başarılı sonuçlar görmemizi sağlayabilecektir.

Anahtar Kelimeler: chatbot, chatgpt, copilot, grok, tıp eğitimi.

INVESTIGATION OF PROCESS PARAMETERS ON DENSITY OF LPBF-MANUFACTURED Co-Cr ALLOY SAMPLES

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ABSTRACT

Laser Powder Bed Fusion (LPBF) enables the precise fabrication of geometrically complex and high-performance metal components, making it particularly suitable for critical jet engine parts in the aerospace industry. Cobalt-chromium (Co-Cr) alloys are widely used in jet engine components due to their excellent high-temperature strength and oxidation resistance, making them ideal candidates for LPBF processing. In this study, the influence of 61 independent LPBF process parameters—including variations in laser power (140–480 W), scan speed (400–1400 mm/s), and hatch distance (60–140 µm)—was investigated in detail. The investigation focused on their effects on the density of Co-Cr alloy samples, measured by Archimedes' principle, and the areal density calculated using ImageJ software. All samples were fabricated using a constant layer thickness (30 µm), laser spot diameter (75 µm), and a chess scan strategy. The experimental results confirm that the optimized parameter settings, such as 410 W laser power, 950 mm/s scan speed, and 75 µm hatch distance, produce densities greater than 8.18 g/cm³ (99.2% areal density) with minimal porosity. In addition, the research highlights the significant influence of volumetric energy density on the quality of the built parts. Low energy densities (<100 J/mm³) lead to incomplete fusion and lack of consolidation, whereas excessively high values (>200 J/mm³) result in keyhole defects due to overmelting. These findings provide a robust basis for optimizing process parameters in the large-scale LPBF

manufacturing of Co-Cr components for demanding aerospace applications requiring high mechanical reliability.

Keywords: Additive manufacturing, laser powder bed fusion, Co-Cr alloys, process optimization, density

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DETECTION OF FUNGAL DISEASES IN SUGAR BEET CULTIVATION AREAS IN BAYBURT PROVINCE

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ABSTRACT

This study aims to identify fungal diseases in sugar beet (*Beta vulgaris* L.) cultivation areas within Bayburt province, located in Turkey's Eastern Black Sea Region. The objective is to determine the prevalence of these diseases and to evaluate the potential phytopathological risks specific to the region. As a strategically important crop for Turkey's agriculture and sugar industry, sugar beet is particularly vulnerable to biotic stress factors, especially fungal pathogens, which can cause significant yield and quality losses.

Field surveys were conducted in three phases throughout the 2024 growing season in the districts of Bayburt. Sugar beet plants showing symptoms of disease were collected and subjected to detailed laboratory analyses using both microscopic and macroscopic diagnostic techniques.

The study reveals that fungal diseases pose a substantial threat to sugar beet production in Bayburt province and directly affect crop productivity. It emphasizes the necessity of implementing region-specific integrated disease management strategies, including the use of resistant cultivars, proper crop rotation, and optimized planting schedules. The findings also underscore the need for farmer education and awareness on disease prevention practices to ensure sustainable agricultural production in the region. The data obtained serve as a valuable reference for agricultural stakeholders and policy developers in the context of plant protection.

Keywords: Sugar beet, Fungal pathogens, plant diseases, field survey

ASSESSMENT OF SOIL QUALITY WITH THE SMAF METHOD

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ABSTRACT

In this research, in the process of evaluating some soil properties on the Bingöl Solhan Plain sample, it was aimed to determine the general soil quality of the Solhan Plain in line with the data obtained from the soil quality parameters selected by taking expert opinion of the soil samples at 0-30 cm depth taken from 85 different coordinates through grids placed at 300 m x 300 m intervals using ArcGIS 10.8 software. Physical property analyses of soil samples taken from the field in the laboratory environment; Soil Texture (Clay, Silt, Sand), Volume Weight, Useful Water Content, Field Capacity, Fading Point. Chemical property analyses; Cation Exchange Capacity, Soil Reaction (pH), Electrical Conductivity (EC), Lime Percentage, Water Displaced Na Amount. Organic matter content was determined for biological property analysis. In the evaluation of soil quality parameters, each parameter was normalised and soil quality index was determined by SMAF model and additive index method. As a result of this evaluation, the physical soil quality score of Solhan Plain varies between 43-88, but it is defined as 'medium quality' since it is between 55-70 quality scores in the score table with an average quality score of 60. Although the chemical soil quality score varies between 50-57, the chemical soil quality is defined as 'low' because it is between 40-55 quality scores with an average quality score of 54. Although the biological soil quality of the area varies between 40-56, the soil quality is defined as 'low' because it is between 40-55 quality scores with an average quality score of 48. Although the general soil quality of the area varies between 50-62, it is defined as 'medium quality' since it is between 55-70 quality scores with an average quality score of 56.

In order for the soils in the study area to fulfil the desired functions; physical, chemical and biological soil quality must be at the desired level. For this reason, maintaining and even improving the functions of soils depends on appropriate management systems and land management. In areas where the quality content is defined as low, the positive effects on the physical, chemical and biological qualities of the soil will be seen in a short time with crop rotation and barnyard manure applications. It is inevitable that the weak properties will get much worse with poor land applications. In this study, it was concluded that the SMAF model can be used as an important tool in the evaluation of soil quality and thus it is important for farmers, land managers and people who have a say in production to make better and more effective decisions regarding sustainable land use and soil health improvement practices.

Keywords: SMAF, soil quality, Solhan Plain, simple additive index.

NEW TREND IN APPLICATION DEVELOPMENT: BENEFITS AND CHALLENGES OF LOW-CODE/NO-CODE PLATFORMS FOR ORGANIZATIONS

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ABSTRACT

In the digital age, developing artificial intelligence technology and the artificial intelligence-based platforms that emerged with it have begun to offer an unprecedented software development environment for both businesses and societies. Low-code/no-code (LCNC) platforms have essentially been an important technological development that has saved application development from the monopoly of software developers and has enabled the emergence of the concept of citizen development in companies. LCNC platforms are a new technology that hides the complexity of coding in the background and allows individuals without formal coding training to develop applications that can solve the problems they encounter in their own work. These platforms have reduced the burden on software developers, contributed to the acceleration of business processes, and significantly supported the digital transformation of businesses by shortening the time it takes to provide digital solutions to problems. In addition, it is also accepted as a breakthrough that supports employees in the development of the most needed digital skills in the digital transformation process, facilitates the learning process, and provides a solution to the software developer gap. Citizen developers, even if they do not have professional coding knowledge, are people who can design, develop and launch applications related to their own fields of work as if they were experienced software developers thanks to LCNC platforms. From the perspective of software developers, LCNC platforms shorten software development cycles from months to days thanks to the visual development environments, pre-created code connectors and smart templates they offer, allowing institutions to automate more professional workflows with scarce IT resources. In this context, this study will draw attention to the basic advantages and challenges that LCNC platforms provide to institutions in the digital transformation process of enterprises. In addition, the contribution of LCNC platforms to the citizen development method and the role of enterprises in the digital transformation process will be discussed. Based on the opportunities and challenges revealed at the end of the study, suggestions will be made on how the field of work can be shaped in the future and what potential research topics can be for researchers.

Keywords: Low code-no code platforms, citizen development, digital transformation, application development

ANALYSIS OF EXERCISE VIDEOS THROUGH AI-ASSISTED VISUAL ASSESSMENT: A COMPARISON BETWEEN CHATGPT 4.5 AND PHYSIOTHERAPIST EVALUATIONS

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ABSTRACT

Objective: The aim of this study is to evaluate the feasibility of visual analysis of YouTube videos featuring the "Cat-Cow" exercise, which is designed to improve spinal mobility, using the ChatGPT 4.5 model, and to compare these assessments with those conducted by an experienced physiotherapist.

Method: In this study, 25 YouTube videos were selected using the keyword "Cat-Cow exercise." The videos were segmented into one-second frames, and the resulting images were evaluated by the ChatGPT 4.5 model according to predefined criteria. The initial assessment employed a seven-item Exercise Quality Scale (scored 0–2). In the second assessment, the overall quality of each video was rated on a 1–5 scale. The same videos were independently evaluated by a physiotherapist with clinical experience using the same criteria. Scores from ChatGPT and the physiotherapist were compared using the Wilcoxon test, Intraclass Correlation Coefficient (ICC), and Bland-Altman analysis.

Results: Based on the Exercise Quality Scale scores, the mean total score assigned by ChatGPT 4.5 was 12.20 ± 1.98, while the physiotherapist's mean score was 10.52 ± 3.62 ($p = 0.018$). A low level of agreement was observed between raters (ICC: 0.360), and the Bland-Altman analysis revealed a mean difference of 1.68. In the overall quality assessment, the mean score given by ChatGPT 4.5 was 4.16 ± 0.75, compared to 3.52 ± 1.19 assigned by the physiotherapist ($p = 0.0058$). ICC remained low (0.373), with a mean difference of 0.64 according to the Bland-Altman analysis.

Conclusion: ChatGPT 4.5 tends to give higher exercise and overall quality scores than the physiotherapist. This suggests that the model has a certain potential in recognizing posture and movement form. However, full agreement with human observation has not been achieved. Therefore, further development of ChatGPT 4.5 is needed to enhance its visual assessment capabilities and ensure greater clinical reliability.

Keywords: ChatGPT 4.5, exercise, YouTube, artificial intelligence, visual analysis

ARTIFICIAL INTELLIGENCE AND EMPLOYEE ENGAGEMENT: OPPORTUNITIES AND CHALLENGES IN HRM

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ABSTRACT

The rapid advancement of digitalization in today's business environment has significantly accelerated the adoption of artificial intelligence (AI) technologies in human resource management (HRM). As businesses strive for more efficient operations, AI has emerged as a key tool in streamlining HR functions. Beyond automating routine administrative tasks, AI increasingly contributes to strategic decision-making processes, thereby enhancing the overall effectiveness and agility of HR functions. This study explores the relationship between AI technologies and employee engagement, focusing on key AI components such as machine learning, artificial neural networks, big data analytics, and process automation. These technologies, which have revolutionized various industries, are now playing a pivotal role in transforming HR practices by providing data-driven insights. From a comprehensive perspective, the analysis examines the influence of these technologies not only on employee engagement but also on associated factors including job satisfaction, motivation, recognition, and employee turnover. As organizations look for ways to foster a positive and productive work environment, understanding how AI impacts these factors is critical. Utilizing a systematic review of contemporary academic literature, this research aims to deepen the understanding of how AI-driven systems shape employee engagement dynamics within organizational settings. By synthesizing recent theoretical and empirical findings, the study identifies both opportunities and challenges presented by the integration of AI into HR practices, highlighting areas where AI can either enhance or hinder employee engagement and retention. Furthermore, the paper outlines several potential directions for future research, with the goal of informing more human-centered and ethically grounded applications of AI in the workplace.

Keywords: Artificial intelligence, employee engagement, human resource management.

TARGET DETECTION BY SYNCHRONIZING SMALL UNMANNED AERIAL VEHICLES (UAVS) AND FACE RECOGNITION SYSTEM

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ABSTRACT

This thesis aims to improve the target detection process by integrating Small Unmanned Aerial Vehicles (UAVs) with artificial intelligence based face recognition systems. The system is designed to detect moving individuals, especially in dynamic and crowded environments. For this purpose, face recognition algorithms such as Convolutional Neural Networks (CNN), Mobile Net, MTCNN, YOLO and Face Net were analyzed and the most suitable models were determined in terms of performance.

The system running on the UAV performs target detection, tracking and identification tasks autonomously by ensuring that hardware and software components work in harmony. In the study, dynamic target tracking, adaptation to environmental variables and real-time processing speed were prioritized. The system provides fast detection of individuals on the move, especially in dense human populations.

Experimental results show that the proposed system speeds up the target detection process and improves the accuracy of target detection in moving and dense environments. In particular, it has great potential for security applications. Due to the flexible nature of UCAVs, the system can be actively used in surveillance, search and rescue, border security and military operations.

The literature review examined the existing research on the integration of UCAVs and face recognition systems and revealed that this work can make significant contributions in areas such as security, search and rescue, and defense. It was observed that existing face recognition systems are largely dependent on fixed cameras and integration with mobile systems is limited.

The system developed in this thesis improves target identification and tracking processes by integrating face recognition algorithms with UAVs. In the tests conducted, it was observed that the system produced successful results in low light conditions and in images taken from different angles. The results show that this approach offers an innovative solution for both academic research and industrial applications.

Keywords: UAVS, Face Recognition, Target Identification, Target Tracking

THERMODYNAMİC FEASIBILITY OF AMMONIA VALORIZATION FOR CLEAN ENERGY AND ENVIRONMENTAL APPLICATIONS

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ABSTRACT

The uncontrolled release of ammonia (NH_3) into the environment poses significant risks to air quality and public health. In response to the growing global demand for safe and sustainable energy alternatives, hydrogen (H_2) fuel has emerged as a promising candidate. This study investigates the thermodynamic feasibility of converting ammonia into valuable products such as hydrogen, nitrogen (N_2), and nitrogen oxides (NO_x), which are useful in various chemical processes. A process modelling and simulation approach was employed to evaluate the oxidative dehydrogenation of ammonia using selected oxidants. The results demonstrate the effectiveness of these oxidants in optimizing hydrogen production and enhancing the yield of other key products. Furthermore, the study highlights the potential for designing environmentally sustainable mechanisms to capture and transform ammonia emissions from various sources, contributing to improved environmental and industrial applications.

Keywords: Process Simulation, Modelling, Environment, Ammonia, Hydrogen, Energy Alternation.

METFORMIN: A BIGUANIDE FOR TYPE 2 DIABETES MANAGEMENT

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ABSTRACT

Metformin is a widely prescribed oral antihyperglycemic agent and a cornerstone in the management of type 2 diabetes mellitus. Belonging to the biguanide class, its primary mechanism of action involves reducing hepatic glucose production and enhancing insulin sensitivity in peripheral tissues, leading to improved glycemic control without typically causing hypoglycemia. Unlike sulfonylureas, metformin does not stimulate insulin secretion.Beyond its glucose-lowering effects, metformin has demonstrated several beneficial effects, including a potential for modest weight loss and improvements in cardiovascular risk factors such as dyslipidemia. It is often favored as a first-line therapy due to its efficacy, safety profile, and relatively low cost.Common adverse effects are primarily gastrointestinal in nature, including nausea, diarrhea, and abdominal discomfort, which often subside with continued use or by taking the medication with food. A rare but serious risk is lactic acidosis, particularly in individuals with impaired renal function, necessitating careful patient selection and monitoring. Long-term use may also be associated with vitamin B12 deficiency in some individuals.In addition to its established role in type 2 diabetes, metformin is also used in the treatment of polycystic ovary syndrome (PCOS) and is being investigated for potential benefits in other conditions, including prediabetes, cancer, and neurodegenerative diseases. Its multifaceted mechanisms of action and favorable profile continue to make it a valuable therapeutic agent.

Keywords: Metformin, oral antihyperglycemic, cardiovascular risk,type 2 diabetes

ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY IN MEDICINAL SYSTEM

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ABSTRACT

Artificial intelligence (AI) is revolutionizing the landscape of drug discovery, offering unprecedented opportunities to accelerate the identification and development of novel therapeutics. By leveraging machine learning, deep learning, and other AI techniques, researchers can analyze vast datasets of biological, chemical, and clinical information to identify potential drug targets, predict drug efficacy and toxicity, and even design novel drug candidates de novo.AI algorithms excel at pattern recognition and predictive modeling, enabling more efficient virtual screening of compound libraries, the optimization of lead compounds, and the prediction of pharmacokinetic and pharmacodynamic properties. This can significantly reduce the time and cost associated with traditional drug discovery pipelines, which are often lengthy and have a high failure rate. Furthermore, AI is playing an increasingly important role in understanding complex biological systems, identifying biomarkers, and personalizing medicine. By integrating diverse data types, AI can help elucidate disease mechanisms and identify patient subpopulations that are most likely to respond to specific treatments. While challenges remain in terms of data quality, interpretability of AI models, and regulatory considerations, the application of artificial intelligence in drug discovery holds immense promise for accelerating the development of life-saving medicines and transforming healthcare.

Keywords: Artificial intelligence, biomarkers, AI algorithms, complex biological systems

RECOMBINANT DNA TECHNOLOGY AND PROTEIN ENGINEERING: POWERFUL TOOLS FOR BIOLOGICAL INNOVATION

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ABSTRACT

Recombinant DNA technology and protein engineering are transformative fields at the forefront of modern biology and biotechnology. Recombinant DNA technology involves the manipulation of genetic material from different sources to create novel DNA molecules, enabling the production of large quantities of specific DNA sequences and the expression of desired proteins in heterologous hosts. This foundational technology underpins numerous applications, including the development of biopharmaceuticals, gene therapy, diagnostics, and genetically modified organisms. Building upon the ability to manipulate DNA, protein engineering focuses on the rational design or directed evolution of proteins with novel or enhanced properties, such as altered stability, catalytic activity, or binding affinity. By employing techniques like site-directed mutagenesis and directed selection, researchers can tailor proteins for specific applications in medicine, industry, and research. This abstract highlights the synergistic power of recombinant DNA technology in providing the genetic blueprints and protein engineering in refining the functional molecules, driving innovation across diverse biological disciplines and offering solutions to global challenges.

Keywords: Recombinant DNA, DNA sequences, genetic blueprints, manipulate DNA, biological disciplines

ASSESSING THE POTENTIAL OF VARIOUS MEDICINAL PLANTS AS ALTERNATIVES TO THE LASOTA VACCINE USED IN POULTRY PRODUCTION FOR NEWCASTLE DISEASE PREVENTION: A REVIEW

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ABSTRACT

Newcastle disease is a major threat to poultry farming worldwide, causing significant economic losses. While the Lasota vaccine is commonly used to prevent the disease, some farmers and researchers are looking for alternative approaches. This review explores the potential of medicinal plants as a natural way to protect poultry from Newcastle disease.Plants like garlic, ginger, and neem have been used for centuries in traditional medicine and have shown promise in boosting the immune system of birds. These plants contain special compounds that can help fight off diseases. This review looks at the current research on using medicinal plants as an alternative to vaccines, highlighting their benefits and challenges.

The findings suggest that medicinal plants could be a useful tool in poultry farming, especially in areas where access to vaccines is limited. However, more research is needed to ensure their safety and effectiveness. By exploring the potential of medicinal plants, we can work towards more sustainable and healthy poultry farming practices. This review aims to contribute to the conversation on natural approaches to animal health and identify areas for further study.

REVIEW ON ORAL DRUG DELIVERY SYSTEM

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ABSTRACT

The oral route is still the most often used method of medication delivery because it is noninvasive, practical, and encourages patient adherence. However, first-pass metabolism and gastrointestinal (GI) barriers (acid pH, enzymes, mucus layers) restrict medication absorption and bioavailability, frequently requiring regular dosage. Recent studies have concentrated on sophisticated oral delivery systems that allow for targeted, regulated, and sustained action in order to overcome these difficulties. Drugs are encapsulated in biocompatible carriers such hydrogel systems, solid lipid and polymeric nanoparticles, liposomes, micelles, and polymeric matrices to prevent degradation during GI transit and release payloads in a sustained or stimuli-responsive manner. Site-specific release is made possible by matrices and coatings that are sensitive to pH or enzymes (enteric polymers or polysaccharide hydrogels dissolve in the intestine or colon).Mucoadhesive or mucus-penetrating compounds, as well as ligand-functionalized nanoparticles (such as antibodies, peptides, and vitamins), improve uptake by particular cells or tissues. Enzyme inhibitors, absorption enhancers, and prodrug methods are examples of co-delivery techniques that increase drug stability and penetration while broadening the range of deliverable substances, such as proteins and peptides. Artificial intelligence (AI)-designed formulations for accurate dosing and release profiles, 3D-printed customized tablets, and ingestible microdevices (microgrippers, electrical sensors) are examples of emerging tactics. These developments have the potential to increase therapeutic indices, maintain therapeutic levels, and enhance drug stability (e.g. permitting oral delivery of difficult biologics). They minimize systemic toxicity by focusing action at disease locations, lowering dose frequency, and maintaining stable plasma concentrations. However, there are still barriers to translation, including interpatient heterogeneity, legal barriers, and manufacturing complexity. All things considered, the combination of innovative carriers and sensitive materials is opening the door for oral medicines of the future that will optimize both safety and efficacy.

INVESTING IN SUSTAINABLE DEVELOPMENT OF REGIONS OF KYRGYZSTAN

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ABSTRACT

This paper examines the significance of investment in the sustainable development of Kyrgyzstan's regions. It highlights the economic, social, and environmental challenges hindering progress, emphasizing the need for increased private investment to supplement government resources. The research integrates qualitative and quantitative methodologies, analyzing statistical data and regulatory frameworks while incorporating insights from local stakeholders.

Findings indicate that economic disparities, environmental degradation and insufficient infrastructure remain key obstacles. While foreign investments are concentrated in specific regions, others face economic stagnation, exacerbating inequality and internal migration. The study underscores the importance of green economy initiatives and blockchain technology in agriculture to enhance transparency, efficiency and environmental sustainability.

Recommendations include fostering policies that attract sustainable investments, improving governance to mitigate corruption and leveraging international partnerships. The study concludes that sustainable investment is vital for fostering resilience, economic diversification and social equity. To ensure a stable and prosperous future, Kyrgyzstan must adopt an integrated approach that balances economic growth with environmental protection and social development.

ANALYSIS OF THE STATE OF FOREIGN INVESTMENT ATTRACTION IN THE REGIONS OF KYRGYZSTAN

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ABSTRACT

Foreign direct investment (FDI) serves as a key catalyst for economic transformation, regional development and sustainable growth. This article provides an in-depth analysis of the state of foreign investment attraction across the regions of Kyrgyzstan, utilizing data from the National Statistical Committee of the Kyrgyz Republic, the National Bank of the Kyrgyz Republic, the World Bank, the Eurasian Development Bank (EDB) and the United Nations Conference on Trade and Development (UNCTAD). The study explores the dynamics of FDI inflows, regional disparities and the underlying factors influencing investment distribution.

The findings reveal that while some regions successfully attract foreign capital, others remain underserved due to structural barriers, regulatory inconsistencies and infrastructural limitations. Policy uncertainty and institutional inefficiencies further complicate the investment climate. However, Kyrgyzstan possesses considerable potential in emerging sectors such as green energy, tourism, agribusiness and digital innovation. By capitalizing on its geographic location and untapped resources, the country can enhance its investment profile and foster sustainable economic diversification.

To strengthen its appeal to international investors, Kyrgyzstan must implement a strategic framework that includes regulatory reforms, enhanced legal protections and streamlined administrative processes. Expanding investment incentives, promoting public-private partnerships (PPPs) and developing region-specific economic clusters can accelerate FDI inflows and ensure a more balanced distribution of investments. Moreover, fostering regional cooperation and establishing transparent, investor-friendly policies will reinforce confidence among foreign stakeholders.

This study offers actionable recommendations to overcome investment bottlenecks and unlock the full potential of Kyrgyzstan’s regions. By addressing key challenges and leveraging competitive advantages, the country can position itself as a dynamic investment hub, driving inclusive economic growth and long-term prosperity.

SEISMIC ANALYSIS OF COMPARITIVE MULTI – STOREY BUILDING

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ABSTRACT

In this modern era urbanization increases day by day, the availability of land is becoming less and cost of land is becoming higher. To meet the requirements of the population, high rise buildings are very much needed. The high-rise buildings are to be designed to resist lateral forces. The analysis of a structural system to determine the deformations and forces induced by applied loads or ground excitation is an essential step in the design of a structure to resist earthquakes. Nowadays multi-storey buildings are consists with different irregularities that can be consider in designing a structure are plan irregularity, vertical irregularity, stiffness irregularity and mass irregularity. In this project, seismic analyses of RCC buildings with mass irregularity at top floor level are carried out. The Model Considered as G+8 having with heavy masses on 8^{th} storey of the building. Structure having the material properties M30 grade for concrete and Fe 550 for reinforcing steel as per IS: 456-2000, with length 30.5m, width 28.5m and each floor height 3m. As per IS: 1893-2016, Mass irregularity is considered to exist where the seismic weight of any storey is more than 150 percent of that of its adjacent storey. Mass irregularity is an important factor which affects the response of the structure under seismic loads. The Seismic analysis will be carried out on Response spectrum analysis in ETABS software.

Keywords: *Mass irregularity, Seismic analysis, Response spectrum analysis and ETABS software*

APPLICATION OF INDUSTRIAL WASTE MATERIALS FOR THE PREPARATION OF GREEN BRICKS

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ABSTRACT

The manufacturing of bricks from industrial waste materials such as fly ash, rice husk, glass powder, lime, and coconut fiber offers a sustainable solution for waste management and conservation of natural resources. This study investigates the feasibility of using these waste materials to produce bricks with desirable physical, mechanical, and thermal properties. The bricks were manufactured using a combination of these waste materials and lime as a binding agent. The results show that the bricks exhibit excellent compressive strength, water absorption, and thermal insulation properties. The use of these waste materials in brick manufacturing reduces the environmental impact of waste disposal, conserves natural resources, and promotes sustainable development. This novel approach has the potential to revolutionize the construction industry by providing a sustainable and eco-friendly alternative to traditional brick manufacturing methods. The rapid growth of industrialization has led to an alarming increase in waste generation, posing significant environmental concerns. This study explores the feasibility of utilizing industrial waste materials, including fly ash, rice husk, glass powder, lime, and coconut fiber, to manufacture sustainable bricks. The bricks were produced using a combination of these waste materials and lime as a binding agent. The physical, mechanical, and thermal properties of the bricks were evaluated, and the results showed excellent compressive strength, water absorption, and thermal insulation properties. The use of these waste materials in brick manufacturing reduces waste disposal costs, conserves natural resources, and mitigates environmental pollution. This comprehensive study demonstrates the potential of industrial waste materials in sustainable brick production, offering a viable solution for the construction industry to adopt eco-friendly practices.

Keywords: *Fly ash, Coconut fiber powder, Glass powder, Lime, Rice husk ash, Compressive strength and Water absorption test*

FROM PANTRY TO BIOLAB: REIMAGINING KITCHEN TYPOLOGIES FOR FUTURE FOOD INNOVATION

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ABSTRACT

The purpose of this research is to explain how kitchens have been redesigned as multifunctional biolabs meant to improve food production and preparation. The main point examined is that there is not enough room in modern kitchens for new biotechnological ideas in cooking, which limits the use of novel food systems. After studying how people interact in the kitchen and assessing their dietary trends, it is clear that the use of biotech tools in kitchens can increase how sustainable and nutritious the food made at home can be. As a result of this transformation, families can produce foods in their homes that are both nutritious and help prevent food insecurity. This research outlines a plan to use every day gathering places to raise awareness about healthy eating and new types of food. All in all, the research suggests a change in how we approach kitchen design, saying that new ideas for kitchen layouts are vital for innovative work in food and better health for the community.

Keywords: Future Kitchen Design; Food Innovation Architecture; Smart Kitchen Systems; Biocentric Design; Home-Based Food Production.

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WASTE NOT: INTEGRATING COMPOSTING AND RESOURCE RECOVERY IN SMART KITCHEN ARCHITECTURE

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ABSTRACT

This research looks into including both composting and resource recovery systems in smart kitchens to help improve how food waste is managed, mainly in urban homes. The research uses a blend of different data collection methods to look into how waste is generated today, what people think about composting technologies, and how successful various waste recovery methods are. It is apparent from the data that households who use smart kitchen composting systems not just reduce the amount of waste, but also benefit by having better attitudes and habits toward being more environmentally friendly. This research explains that better handling of waste and lowering food waste can positively impact public health and the quality of the environment people live in. Additionally, research shows that using sustainable methods in kitchens can improve community health, promote nutrition and waste education, and strengthen efforts to create a sustainable environment in cities. As a result, this study suggests that the use of smart kitchens and effective composting combined with recovery of resources has the power to develop eco-friendly lifestyles in cities and improve public health, paving the way for a responsible use of all resources.

Keywords: Smart Kitchen Architecture; Composting Systems; Resource Recovery; Food Waste Management; Sustainable Domestic Infrastructure.

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IoT AND AI IN THE KITCHEN: ARCHITECTURAL IMPLICATIONS OF CONNECTED FOOD SYSTEMS

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ABSTRACT

The research looks at how joining IoT and AI with food systems in kitchens can help optimize the area, make the systems effective, and enhance user experience, all the while promoting a sustainable and efficient approach. With the combined use of both qualitative and quantitative methods, we gathered information through case studies and interviews of kitchen stakeholders, analyzed energy and food waste levels, and reviewed user satisfaction. The research suggests that using IoT and AI in kitchens can make the working environment more friendly, help make meal preparation faster, and lead to healthier diet habits. Furthermore, the study explains how using technology can result in both better energy efficiency and a reduction of food waste. As a result, designing smart kitchens can help individuals enjoy a better experience and also benefit people by reducing the impact of food systems on the environment. Beyond cooking, this points to the great benefit for healthcare of using these smart technologies that help us lead healthier lives and lower our impact on nature. Because of this study, people can better see the need for new designs that support health-conscious and eco-friendly living within homes.

Keywords: Smart Kitchen Design; Internet of Things (IoT); Artificial Intelligence (AI); Intelligent Domestic Architecture; Adaptive Kitchen Environments.

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DESIGNING KITCHENS FOR NUTRITIONAL WELLNESS: A BEHAVIORAL ARCHITECTURE APPROACH

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ABSTRACT

It explores ways to improve nutrition in the kitchen by rearranging design elements, using behavioral architecture and acknowledging how physical places can affect food-related actions and decisions. The study mixes interview-based qualitative data with survey-based quantitative data to pinpoint aspects of design that help users follow healthier diets. The results show that the arrangement of the space, the availability of healthy food, and the use of natural lighting impact users' decisions and help them maintain a healthy lifestyle. They are important as they can help design health strategies against diseases caused by unhealthy diets and point to the role of environment in promoting health at the community level. Moreover, the findings bring attention to the areas of nutrition and architecture, proving that uniting different experts benefits the health of people living in different areas. It supports the development of more knowledge by explain how cooking spaces can be structured to improve health and offers suggestions for how design interventions at home can improve health and lower money spent on healthcare for diet-related problems.

Keywords: Behavioral Architecture; Nutritional Wellness; Health-Oriented Kitchen Design; Food Environment Design; Architectural Cues for Behavior Change.

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IMPROVING THE RECOVERY OF BIOACTIVE MOLECULES FROM COFFEE WASTE THROUGH INNOVATIVE THERMO-MECHANICAL AND MICROWAVE-ASSISTED METHODS

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ABSTRACT

The preparation of 1 kg of instant coffee generates approximately 2 kg of wet spent coffee grounds, typically considered waste. However, this by-product still contains high-value bioactive compounds, particularly sought after in wellness and health-related sectors.

In this study, the extraction of these compounds was carried out by combining the Controlled Instantaneous Pressure Drop (DIC) process with Microwave-Assisted Extraction (MAE). The DIC process was used as a texturizing pretreatment to enhance the extraction efficiency of bioactive compounds from spent coffee grounds.

Response Surface Methodology (RSM) was used to optimize the DIC pretreatment process based on two responses: total polyphenol content and antioxidant activity. The statistical influence of four factors was evaluated: saturated steam pressure (P), thermal processing time (t), number of cycles (C), and moisture content (W). A significant increase in both total polyphenol concentration and antioxidant activity was observed in extracts from DIC-treated samples. Compared to untreated samples, polyphenol content increased from 26.40 to 31.97 mg GAE/g dry matter, and antioxidant activity increased from 82.61% to 89.55% under the following conditions: P = 0.25 MPa, C = 7, t = 60 s, and W = 16%.

The total duration of the process was 6 minutes, including a 1-minute DIC pretreatment followed by a 5-minute MAE, resulting in a 21% increase in total polyphenol concentration compared to MAE alone. Combining DIC with MAE offers an innovative approach that optimizes processing time while improving the extraction yields of antioxidant compounds.

Keywords: Spent coffee grounds, bioactive compounds, phenolic compounds, antioxidants, DIC, microwave.

ANTIDIABETIC ACTIVITY OF *Grewia asiatica* SEED EXTRACT IN STREPTOZOTOCIN INDUCED DIABETIC RATS

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ABSTRACT

Diabetes mellitus is a metabolic disorder that inhibits the ability of the body to produce or utilize insulin. The aim of this study was to explore the antidiabetic potential of ethanolic extract of *Grewia asiatica* seeds. A total 36 rats were used and equally divided into six groups, each group was contain six (6) rats. First group was normal control group (daily routine feed diet); second group was kept as diabetic control (diabetes was induced with 30% of high fat diet (HFD) and single inj. of streptozotocin 50mg/kg); group 3 was standard group (metformin 200mg/kg); group 4 was test group of low dose (100 mg/kg); group 5 was test group of medium dose (150 mg/kg); group 6 was given high dose (200mg/kg).Antidiabetic activity of *G. asiatica* was determined. FBG and body weight were measured on a weekly basis. At 28th day, rats were decapitated and blood samples were collected. Serum glucose, Insulin and C-peptide levels were measured. Results indicated a significant decrease in serum glucose and improvement in serum insulin levels in *G. asiatica* treated groups. The plant under study also improved the insulin sensitivity and reduced insulin resistance. The results of the present study reveal the antidiabetic potential of *G. asiatica* seeds.

Keywords: Diabetes mellitus; *Grewia asiatica;* Insulin resistance; FBG

*CORDIA SINESIS*AMELIORATES DIABETES ASSOCIATED DYSLIPIDEMIA IN STZ INDUCED DIABETIC RATS

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ABSTRACT

Diabetes Mellitus refers to a collection of metabolic disorders that result in elevated blood glucose level (hyperglycemia). Dyslipidemia, a metabolic disorder that is frequently linked to diabetes, is typified by a variety of quantitative and qualitative alterations in lipids and lipoproteins. The seeds of *Cordia sinensis* possess strong sticking and emulsifying qualities that make them suitable for use as antioxidant carriers.This study aims to explore the ameliorative effect of *C.sinesis*against diabetes-associated dyslipidemia. In this study, a total of thirty-six wistar rats were allocated into 6 experimental groups. Group 1served as the normal control (normal feed diet). Group 2 was diabetic control group (diabetes was induced with 30% high-fat diet (HFD) using a low dose of streptozotocin (55mg/kg body weight) intraperitoneally). Group 3, the standard group,received Metformin (250 mg/kg). Groups 4, 5,and 6 were test groups, treated with ethyl acetate extract of *C.sinensis* at doses of 150 mg/kg, 250 mg/kg, and 350 mg/kg, respectively, for 28 days.At the end of the study,serum and tissue samples were collected andbiochemical markers (serum glucose, insulin), insulin resistance markers, and lipid profiles were measured. ANOVA was used to evaluate the data, and Tukey's test was used to assess significance among groups. Results demonstrated that C.*sinesis* significantly reduced the serum glucose levels and significantly improved the serum insulin levels. Insulin resistance was also reduced in *C.sinesis* treated rats. *C.sinesis* significantly improved the lipid profile via significant reduction in TC, TG, LDL and VLDL levels and appreciable improvement in HDL levels in treated groups.

Keywords:*C.sinesis;* Diabetes Mellitus; Lipid profile; Insulin resistance; HDL

SURVEY OF PARASITOIDS ASSOCIATED WITH WHITE PEACH SCALE (*Pseudaulacaspis pentagona*) IN KIWI ORCHARDS OF GILAN PROVINCE, IRAN

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ABSTRACT

White peach scale, *Pseudaulacaspis pentagona* (Hemiptera: Diaspididae), is a significant polyphagous and economically harmful pest of kiwi gardens and some fruit trees in northern Iran. The present study was conducted during 2023–2024 to identify and document the hymenopteran parasitoid species of *P. pentagona* on two kiwi gardens in Gilan province. Infested branches were systematically gathered within a predetermined time, and emerging parasitoids were bred and identified with the aid of detailed morphological and taxonomic keys. Our survey isolated six parasitoid species that attack *P. pentagona*, which are important natural enemies that play an important part in its biological control in the region. Among these, *Encarsia berlesei* was the most dominant specie, followed by five other parasitoids already documented in Iran. The occurrence and population dynamics of the parasitoids support their potential role in integrated pest management (IPM) schemes for sustainable white peach scale control of kiwi orchards. The current investigation presents valuable baseline data to promote the following biological control research and implementation of sound pest management policies in Gilan province.

Keywords: *Pseudaulacaspis pentagona*, Parasitoids, Kiwi Orchards, Biological Control, IPM

A MOLECULAR MODELING APPROACH TO SUSTAINABLE DRUG DELIVERY: IMPROVING IBUPROFEN SOLUBILITY THROUGH DEEP EUTECTIC SOLVENTS

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ABSTRACT

Ibuprofen, a widely prescribed non-steroidal anti-inflammatory drug (NSAID), is commonly used to alleviate pain, inflammation, and fever. However, its poor aqueous solubility significantly limits its oral bioavailability and presents challenges in developing liquid formulations, particularly for pediatric and dysphagic patients. Traditional solubility enhancement methods—such as solid dispersions, emulsification, and surfactant incorporation—often suffer from drawbacks including chemical instability and toxicity concerns. As a sustainable alternative, deep eutectic solvents (DESs) have emerged as promising solubilizing agents, composed of biodegradable, non-toxic components capable of forming hydrogen bonds. In this study, a DES comprising choline chloride and propylene glycol was investigated for its potential to enhance the solubility of ibuprofen using quantum mechanical methods. These calculations were employed to explore the molecular interactions between ibuprofen and the DES components. The findings would be useful for predicting the prospect of utilizing the selected DES in enhancing the solubility of the drug, offering a potential alternative to water as a solvent. By integrating quantum chemical modeling with green chemistry principles, this work contributes to the development of safer, more effective, and environmentally sustainable pharmaceutical formulations.

Keyword: Deep Eutectic Solvent, Solubility, Drug Delivery, Green Solvent.

FIGHTING DIABETES WITH HERBAL TECHNOLOGY

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ABSTRACT

Diabetes mellitus, particularly type 2 diabetes, has emerged as a global health concern, affecting over 500 million people worldwide. Characterized by chronic hyperglycemia and associated with complications such as cardiovascular disease, neuropathy, and kidney failure, diabetes demands effective and sustainable treatment strategies. Although conventional therapies, including insulin injections and oral hypoglycemic agents, have proven effective in managing blood glucose levels, they are often accompanied by undesirable side effects, high costs, and limited accessibility—especially in low- and middle-income countries. This has led to increased interest in alternative treatment modalities, particularly those derived from traditional medicine and plant-based therapies.Herbal medicine has been used for centuries in systems such as Ayurveda, Traditional Chinese Medicine (TCM), and African traditional medicine to treat diabetes. With the advancement of herbal technology—defined as the scientific development and modernization of plant-based therapies—there is renewed potential to integrate these remedies into mainstream diabetes care. Herbal technology not only validates traditional practices through rigorous scientific research but also improves the bioavailability and therapeutic efficiency of plant compounds using modern tools such as nano-formulations and phytopharmaceuticals.Plant-based compounds, including alkaloids, flavonoids, terpenoids, saponins, and tannins, exhibit hypoglycemic effects through various mechanisms. These include stimulating insulin secretion, enhancing insulin sensitivity, inhibiting intestinal glucose absorption, and promoting pancreatic beta-cell regeneration. Several herbs have been extensively studied for their antidiabetic properties. Bitter melon (Momordica charantia) contains insulin-mimetic compounds like charantin and polypeptide-p, while fenugreek (Trigonella foenum-graecum) is rich in soluble fiber that slows glucose absorption and improves glycemic control. Gymnema sylvestre is known for regenerating beta cells and reducing sugar cravings, cinnamon (Cinnamomum verum or cassia) enhances insulin receptor activity, and aloe vera demonstrates lipid-lowering and hypoglycemic effects.Modern herbal technology has enabled the creation of advanced delivery systems such as nanoparticles, encapsulated extracts, and transdermal patches to increase the potency and controlled release of these phytochemicals. These innovations are overcoming traditional limitations such as poor solubility and low bioavailability. Concurrently, a growing body of scientific literature supports the efficacy and safety of herbal remedies in clinical settings, though more high-quality randomized controlled trials are needed.Despite the promising potential, challenges remain. Standardization of herbal formulations, regulatory approvals, and quality control are critical issues that need attention. Furthermore, interactions with conventional drugs and variability in plant composition due to environmental factors must be carefully addressed. However, with proper integration into healthcare systems, herbal technology could offer an affordable, natural, and culturally accepted approach to managing diabetes.In conclusion, fighting diabetes with herbal technology presents a viable complement or alternative to conventional treatments. By combining ancient wisdom with modern scientific advancements, herbal medicine stands poised to play a pivotal role in the global fight against diabetes, especially in resource-limited settings.

Keywords: Diabetes Mellitus,Herbal Medicine,Phytochemicals,Insulin Sensitivity,Blood Glucose Control,Traditional Medicine,Bitter Melon,Fenugreek,Gymnema Sylvestre,Nano-herbal Formulations,Plant-based Therapy,Hypoglycemic Agents,Alternative Medicine,Herbal Technology,Type 2 Diabetes Management

PHARMACY SERVICES FOR PATIENTS WITH ALLERGIES

The Management Of Allergic Rhinitis By Pharmacist İn Public Services

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ABSTRACT

Allergic rhinitis has been identified as a major respiratory disease that places a significant burden on patients and the healthcare system. Nevertheless, the management of allergic rhinitis is challenging for both patients and practitioners. Pharmacists have been recognised as strategic in providing advice for allergic avoidance, disease information, and pharmacological care for allergic rhinitis management. This role has been underutilised in the public health service sector in Malaysia due to variation in practice, regulation, and health system structures when compared to the international guidelines. This article proposed a PhaRmacISt-led Education Model (AR-PRISE) that includes explicit patient education materials and an algorithm for structured counselling by pharmacists in the management of patients with allergic rhinitis.

Keywords: Allergic rhinitis, Public health service, Pharmacist, Patient education, Educational model

A COMPREHENSIVE REVIEW ON NUTRACEUTICALS: THERAPY SUPPORT AND FORMULATION CHALLENGES

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ABSTRACT

Nutraceuticals are the nourishing components (hybrid of nutrition and pharmaceuticals) that are biologically active and possess capability for maintaining optimal health and benefits. These products play a significant role in human health care and its endurance, most importantly for the future therapeutic development. Nutraceuticals have received recognition due to their nutritional benefits along with therapeutic effects and safety profile. Nutraceuticals are globally growing in the field of services such as health care promotion, disease reduction, etc. Various drug nutraceutical interactions have also been elaborated with various examples in this review. Several patents on nutraceuticals in agricultural applications and in various diseases have been stated in the last section of review, which confirms the exponential growth of nutraceuticals' market value. Nutraceuticals have been used not only for nutrition but also as a support therapy for the prevention and treatment of various diseases, such as to reduce side effects of cancer chemotherapy and radiotherapy. Diverse novel nanoformulation approaches tend to overcome challenges involved in formulation development of nutraceuticals. Prior information on various interactions with drugs may help in preventing any deleterious effects of nutraceuticals products. Nanotechnology also leads to the generation of micronized dietary products and other nutraceutical supplements with improved health benefits. In this review article, the latest key findings (clinical studies) on nutraceuticals that show the therapeutic action of nutraceutical's bioactive molecules on various diseases have also been discussed.

Keywords: cardiovascular diseases, interactions, nutrition, prevention, therapeutics

MENİNGITIS: INFLAMMATION OF THE BRAIN AND SPINAL CORD MEMBRANES

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ABSTRACT

Meningitis, an inflammation of the protective membranes (meninges) surrounding the brain and spinal cord, poses a significant global health burden. This condition can arise from various infectious agents, primarily bacteria, viruses, and fungi, as well as non-infectious causes. The clinical presentation of meningitis often includes fever, headache, neck stiffness, photophobia, and altered mental status, although symptoms can vary with the etiological agent and patient age. Prompt diagnosis and initiation of appropriate treatment are critical to prevent severe complications such as neurological deficits, hearing loss, seizures, and even death.This overview will discuss the diverse etiologies of meningitis, highlighting the key pathogens and their mechanisms of infection. It will also delve into the pathophysiology of meningeal inflammation, exploring the host immune response and the factors contributing to neuronal injury. Furthermore, current diagnostic approaches, including lumbar puncture for cerebrospinal fluid (CSF) analysis and neuroimaging techniques, will be examined. Finally, the principles of management, encompassing antimicrobial therapy for bacterial meningitis, supportive care for viral meningitis, and emerging therapeutic strategies, will be addressed, emphasizing the importance of timely and targeted interventions to improve patient outcomes and reduce long-term sequelae.

RABIES DISEASE

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ABSTRACT

Rabies is a lethal viral infection that leads to brain inflammation and is mainly spread through animal bites, especially from dogs worldwide and bats in North America. Immediate wound treatment and the timely administration of rabies vaccine and immune globulin after exposure can help prevent the disease. However, once symptoms arise, rabies is nearly always fatal, presenting distinctive signs such as hydrophobia, the presence of Negri bodies in neurons, and inflammatory changes. Diagnosis can be established by identifying rabies virus antigens or RNA, as well as through serological tests, but there is currently no effective treatment available.

EVALUATING THE METABOLIC EFFECTS OF *Garcinia cambogia* SUPPLEMENTATION IN Streptozotocin-NICOTINAMIDE-INDUCED TYPE 2 DIABETIC RATS

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ABSTRACT

Introduction: *Garcinia cambogia* (GC), a tropical fruit rich in hydroxycitric acid (HCA), is widely used as a weight-loss supplement due to its purported effects on appetite suppression, lipid metabolism, and glycemic control. HCA inhibits ATP citrate-lyase, potentially reducing fatty acid synthesis and improving metabolic parameters in insulin resistance (IR) and type 2 diabetes mellitus (T2DM). This study investigated the effects of GC supplementation on fasting blood glucose (FBG), insulin, leptin, BMI, and pancreatic histopathology in streptozotocin-nicotinamide (STZ-NA)-induced T2DM rats.

Materials & Methods: Thirty-six adult Wistar rats were divided into six groups (n=6): non-diabetic control, diabetic untreated control, diabetic standard treatment, and three diabetic groups receiving GC at 10, 100, or 200 mg/kg/day for four weeks. Metabolic parameters and pancreatic tissue were analyzed post-treatment.

Results: Results showed no significant improvement in FBG or insulin levels in GC-treated groups compared to diabetic controls ($p>0.05$). However, leptin levels were significantly reduced at higher GC doses (100 and 200 mg/kg; $p<0.05$). Histopathological analysis revealed partial preservation of Langerhans islet size and architecture in GC-treated groups, particularly at 200 mg/kg, though not reaching non-diabetic levels. No significant changes in BMI were observed.

Conclusion: While GC supplementation did not fully restore glycemic control, its dose-dependent reduction in leptin and modest pancreatic tissue improvements suggest potential metabolic benefits. Further studies are needed to elucidate GC's mechanisms in T2DM management.

Keywords: *Garcinia Cambogia*, Type 2 diabetes, Leptin, BMI, Pancreatic histopathology

INFLUENCE OF MWCNT-ENHANCED MINIMUM QUANTITY LUBRICATION ON POWER CONSUMPTION AND SURFACE ROUGHNESS IN FACE MILLING OF AISI 304 STAINLESS STEEL

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ABSTRACT

AISI 304 stainless steel, an austenitic alloy, is widely utilized in industries such as automotive, petrochemical, and food processing due to its favorable mechanical properties and corrosion resistance, primarily attributed to its chromium and nickel content. However, its low thermal conductivity produces high cutting forces and excessive heat generation during machining, leading to accelerated tool wear and reduced efficiency. Optimizing cutting parameters and tool materials is crucial for improving tool life and surface quality. In this context, the Minimum Quantity Lubrication (MQL) technique, which delivers a small but adequate amount of lubricant directly to the cutting zone, is key in enhancing machining performance while supporting sustainable manufacturing. In this study, the machinability of AISI 316 stainless steel during face milling was investigated under three different cutting conditions: dry, MQL, and nano-MQL with 0.5 vol.% multi-walled carbon nanotube (MWCNT). LUBform B water-based metal lubricant was used as a cutting fluid in the MQL process. A total of 27 experiments were conducted using feeds of 0.05, 0.1, and 0.15 mm/tooth and cutting speeds of 100, 200, and 300 m/min. Surface roughness and power consumption were analyzed as primary indicators of performance. The results showed that both surface roughness and power consumption increased with higher feeds; however, at a cutting speed of 200 m/min, both parameters initially decreased and then increased. MQL was found to improve surface quality and reduce power

consumption. Incorporating MWCNTs in the nano-MQL condition further enhanced these improvements. The best surface roughness (0.31 μm) and lowest power consumption (1,161 W) were achieved under nano-MQL conditions, with a feed of 0.05 mm/tooth and a cutting speed of 200 m/min. From the perspective of sustainable machining, it was found that the MWCNT-reinforced MQL cutting environment has a significant impact on surface quality and power consumption.

Keywords: AISI 304 stainless steel, Face milling, MWCNT, MQL, Surface roughness, Power consumption.

THE EFFECTS OF MOLECULAR WEIGHT AND COATING CONDITIONS ON THE SURFACE WETTABILITY OF PMMA FILMS

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ABSTRACT

Polymethylmethacrylate (PMMA) is widely used in industry due to its optical transparency, sufficient mechanical strength, ease of processing, and good film-forming ability. Controlling the surface wettability of PMMA over a wide range without the use of external additives is critical for improving its applicability in surface-related technologies. In this study, the effects of the molecular weight of PMMA and coating conditions (polymer concentration and solvent type) on the surface wettability of PMMA films were investigated. For this purpose, polymers of methyl methacrylate (MMA) were synthesized by a free radical process in toluene. Polymerizations were carried out in a 250 ml three-neck round-bottom glass reactor under a reflux condenser using a mechanical stirrer. Reactions were performed at 75°C with a duration time of 24 h using benzoyl peroxide (BPO) as the initiator. PMMA samples with varying molecular weights were produced by feeding different amounts of BPO into the reaction medium. At the end of the reaction, the polymer products were precipitated in a cold methanol/water (80/20 vol.%) mixture and were dried in a vacuum oven until constant weight was attained. The molecular weight values of the synthesized polymers were evaluated based on intrinsic viscosity, which was calculated from the relative viscosities determined using a Ubbelohde-type viscometer in toluene at 25°C. Thin films were subsequently prepared by dip-coating glass slides in polymer solutions, and their water wettability was evaluated by contact angle measurements. As a result, it was found that the water contact angle values of the obtained surfaces ranged between 67° and 77°, depending on the molecular weight of the synthesized polymers, the type of coating solvent used (toluene, chloroform, and tetrahydrofuran), and the polymer concentration in the coating solution. Our studies are ongoing to achieve enhanced control over the surface wettability of PMMA films by targeting a wider contact angle range.

Keywords: Polymethylmethacrylate, molecular weight, coating, wettability, contact angle.

EFFECTS OF HELICASE PROTEIN MUTATIONS IN AMERICAN ISOLATES OF SARS-CoV-2

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ABSTRACT

COVID-19 is a viral disease in which severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2) is the pathogenic agent. Non-structural protein-13 (helicase) of SARS-CoV-2 has a vital role in the viral genome. SARS-CoV-2 helicase is at the center of antiviral drug studies to be developed to suppress viral replication. Mutations may affect the course of the disease and the responses to antivirals by causing changes in protein structure and stability. In this study, the changes that mutations in nsp13, which encodes the SARS-CoV-2 helicase protein, may cause in protein structure and stability were investigated to contribute to the understanding of the course of the disease and the development of valid antivirals.

The sequence data of 2483 American isolates infected with the SARS-CoV-2 virus were aligned using Mega XI software. The nine mutations (Ser36Pro, Thr127Asn, His164Tyr, Met233Ile, Tyr324Cys, Ala368Val, Ala389Val, Arg394Cys, Thr599Ile) in American isolates were identified. Mutant protein structures were modeled with the RosettaFold. Model quality was evaluated using Molprobity and QMEAN tools. The model quality scores were found to be within the acceptable range. The effects of mutations on protein structure and stability were analyzed using SDM2, mCSM, DUET and DynaMut2 tools. The mutations (Ser36Pro, Thr127Asn, His164Tyr, Met233Ile, Thr324Cys, Ala368Val, Ala389Val, Arg392Cys, Thr599Ile) altered in protein stability ($-1.893 \leq \Delta\Delta G_{stability} \leq +1.51$).

Consequently, topological and stability changes in nsp13 may lead to changes in the effectiveness of therapeutics. The mutations in American isolates may lead to the emergence of different phenotypes in terms of viral activity. Alternative treatment approaches in various geographical regions can make the fight against the virus successful.

Keywords: SARS-CoV-2, COVID-19, nsp13, helicase, mutation, protein stability

CHANGES IN THE SPIKE PROTEIN OF THE SARS-CoV-2 XBB.1.5 VARIANT

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ABSTRACT

Coronavirus Disease 2019 (COVID19), in which severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) is the etiological agent, is one of the most important health problems of the twenty-first century. Spike protein is one of the important drug and vaccine target structures because it binds to the ACE2 receptor during the viral invasion process and activates the cell entry process. Changes in this structure may alter the host immune response and the efficacy of drugs/vaccines. In this study, the changes in protein structure, stability, and peptide presentation of the SARS CoV-2 spike protein XBB.1.5 variant were investigated using in-silico methods in order to contribute to the development of new and valid therapeutics. SWISS-MODEL and RoseTTAFold modeled the changes in protein three-dimensional structure caused by mutations. Changes in protein stability were analysed with mCSM, DDMut, DUET and DynaMut2 and the effects of mutations on protein function were analyzed with Provean, SIFT and PolPhen2 tools. Changes in protein dynamic structure were evaluated with elastic network models. The effects of mutations on antigenic determinants were tested using Bepipred Linear, Emini Surface Accessibility and Kolaskar & Tongaonkar antigenicity algorithms. Of the 38 mutations detected in the SARS-CoV-2 XBB.1.5 variant, 22 were found to be in the receptor binding site, which is important in the interaction of the virus with the host cell. Protein stability analyses revealed that 21% of the mutations caused an increase in protein stability while 81% caused an increase in instability ($-2.902 \leq \Delta\Delta G \leq +1.82$). It was found that 44.7% of the mutations could have deleterious effects on protein function. XBB.1.5 mutations were found to alter the antigenic determinant profile. We found that four highly conserved antigenic determinants that were found to be conserved in many variants were altered in the XBB.1.5 variant. Decreased stability, increased instability, and movement appear to result in increased receptor affinity, infectivity, and virulence. This study provides a structural framework for understanding the possible effects of alterations caused by SARS-CoV-2 S protein XBB.1.5. mutations on functional properties.

Keywords: SARS-CoV-2, COVID19, spike, XBB.1.5, mutation, epitope

DIFFERENT PROGESTERONE-SUPPORTED ESTRUS SYNCHRONISATION PROTOCOLS IN HEIFERS

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ABSTRACT

Although certain fixed-time artificial insemination (FTAI) protocols, which are widely used in cows to reduce labour requirements significantly, have also been applied to heifers with generally favourable outcomes, optimising these protocols for heifers remains an area requiring further research. Timely intervention in the oestrous cycles of heifers is economically crucial. In this study, conducted on 100 heifers at the Kelkit feedlot farm in Gümüşhane Province, the animals were randomly divided into five groups. The control group (n=20) underwent no hormonal treatment; insemination was performed based on observed estrus. In Group 1 (n=20), GnRH was administered and progesterone implants were inserted on Day 0; on Day 5, PGF2α was administered and the implants were removed; on Day 8, GnRH was administered followed by insemination. Group 2 (n=20) followed the same protocol as Group 1, with an additional insemination on Day 9. In Group 3 (n=20), GnRH and progesterone implants were applied on Day 0; PGF2α was administered and implants were removed on Day 8; GnRH was administered and insemination performed on Day 11. Group 4 (n=20) followed the same schedule as Group 3 with an additional insemination on Day 12. Pregnancy rates after the first, second, and third inseminations were as follows: Control group – 30%, 75%, and 80%, respectively; Group 1 – 65%, 65%, and 70%; Group 2 – 80%, 80%, and 90%; Group 3 – 30%, 40%, and 45%; Group 4 – 15%, 20%, and 25%. The highest pregnancy rate was achieved in Group 2, suggesting that the simplified protocol, when combined with double insemination, significantly enhances reproductive outcomes in heifers.

Keywords: Heifer, pregnancy rate, estrus, synchronisation, artificial insemination

DÜVELERDE PROGESTERON DESTEKLİ FARKLI ÖSTRÜS SENKRONİZASYON PROTOKOLLERİ

ÖZET

İneklerde uygulanan ve ciddi iş gücü tasarrufu sağlayan sabit zamanlı suni tohumlama protokollerinin bazıları düvelerde de uygulanmakta ve çoğu zaman çok iyi sonuçlar alınıyor olmasına rağmen hala geliştirilmesi gereken bir konu olduğu bilinmektedir. Düvelerin östrüs sikluslarına çok geç olmadan müdahale edilmesinin gerektiği ekonomik olarak önemli bir konudur. Gümüşhane İl'inde Kelkit besi çiftliğinde 100 düve üzerinde gerçekleştirilen bu çalışmada, rastgele 5 gruba ayrılan düvelere Kontrol grubuna (n=20); Hiçbir uygulama yapılmadan östrüsleri izlenerek tohumlama yapılmış, Grup 1 (n=20); 0. Gün: GnRH + Progesteron implantların takılması, 5. Gün $PGF_2\alpha$ + Progesteron implantların çıkartılması, 8. Gün GnRH + tohumlama, Grup 2 (n=20): 0. Gün: GnRH + Progesteron implantların takılması, 5. Gün $PGF_2\alpha$ + Progesteron implantların çıkartılması, 8. Gün GnRH + tohumlama, 9. Gün tohumlama yapılmış, Grup 3 (n=20): 0. Gün: GnRH + Progesteron implantların takılması, 8. Gün $PGF_2\alpha$ + Progesteron implantların çıkartılması, 11. Gün GnRH + tohumlama yapılmış, Grup 4 (n=20): 0. Gün: GnRH + Progesteron implantların takılması, 8. Gün $PGF_2\alpha$ + Progesteron implantların çıkartılması, 11. Gün GnRH + tohumlama, 12. Gün tohumlama yapılmıştır. Tohumlamalar sonucunda elde edilen gebelik sonuçlarına göre Kontrol grubunda 1. Tohumlamalar sonucunda %30, 2. Tohumlamalar sonucunda %75 ve 3. Tohumlamalar sonucunda %80 gebelik, Grup 1'de; 1. Tohumlamalar sonucunda %65, 2. Tohumlamalar sonucunda %65 ve 3. Tohumlamalar sonucunda %70 gebelik, Grup 2'de; 1. Tohumlamalar sonucunda %80, 2. Tohumlamalar sonucunda %80 ve 3. Tohumlamalar sonucunda %90 gebelik, Grup 3'te; 1. Tohumlamalar sonucunda %30, 2. Tohumlamalar sonucunda %40 ve 3. Tohumlamalar sonucunda %45 gebelik, Grup 4'de; 1. Tohumlamalar sonucunda %15, 2. Tohumlamalar sonucunda %20 ve 3. Tohumlamalar sonucunda %25 gebelik elde edilmiş olup en başarılı grubun Grup 2 olduğu sonucuna varılmıştır. Gebelik sonuçlarının farklı çıkmasının sebebinin sade bir uygulama olması ve çift tohumlama ile programın desteklenmesi sonucuna varılmıştır.

Anahtar Kelimeler: Düve, gebelik oranı, östrüs, senkronizasyon, suni tohumlama

INVESTIGATION OF THE ANTICARCINOSEROGEN ACTIVITY OF CHESTNUT (*Aesculus hippocastanum* L.) PLANT AGAINST BREAST CANCER CELLS

AT KESTANESİ (*Aesculus hippocastanum* L.) BİTKİSİNİN GÖĞÜS KANSERİ HÜCRELERİNE KARŞI ANTİKANSEROJEN AKTİVİTESİNİN İNCELENMESİ

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ABSTRACT

Horse chestnut (Aescculus hippocastanum L.) is a tree that can grow up to 25 meters tall, has 5-7 leaflets, and its flowers are usually white and rarely red. Its fruit structure is a capsule containing 1-3 seeds. Although its homeland is India, it can also be observed as an ornamental plant in Europe and Turkey.

Since horse chestnut is in the class of medicinal plants, it has therapeutic or symptom-reducing properties against a number of diseases. The main active compound of this plant, Aescin, has pharmacodynamic, anti-edema, anti-inflammatory and antitumor properties. Studies have observed that horse chestnut has therapeutic effects on diseases such as hemorrhoids, wound and skin sensitivities, cough, and rheumatism. In addition, it is known to exhibit anticancer activity against various types of cancer.

The aim of our study is to investigate the effect of horse chestnut fruit and peel extracts prepared with methanol, ethyl alcohol and ethyl acetate on the proliferation of breast cancer cells (MCF-7). To achieve this aim, 7500 cells were cultured in 96 well plates. The next day, chestnut extracts were applied to the cells in the concentration range of 0.1-100 µM. After 24 hours of incubation, MTT solution was applied and measured at 540 nm wavelength. IC50 values of each extracts were calculated with the obtained results. It was found that the fruit extract had a stronger antiproliferative effect than peel extracts. It was observed that methanol and ethyl alcohol extracts inhibited the proliferation of MCF-7 cells in a dose-dependent manner. In the next stages, it is planned to investigate how these extracts affect the morphology, proliferation, invasion and migration properties of cancer cells.

Keywords: Horse chestnut, anticancer, breast cancer.

SPIKING NEURAL NETWORKS FOR EARLY SKIN CANCER DETECTION: A DELTA-MODULATION-BASED APPROACH ON HAM10000

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ABSTRACT

Skin cancer is one of the most prevalent and potentially life-threatening forms of cancer, worldwide. Early and accurate diagnosis is crucial for effective treatment; however, it remains a challenging task because of the visual similarity of various skin lesion types. In recent years, Spiking Neural Networks (SNNs), which mimic biological neural processing, have gained attention as promising alternatives to conventional deep learning methods in neuromorphic computing tasks. In this study, we propose a binary rate-coded spiking SNN based on delta modulation for skin lesion classification evaluated using the HAM10000 dataset. This study focuses on the binary classification of nevus (benign) and akiec (malignant) lesion types. The preprocessing steps include grayscale conversion and delta-modulation-based spike encoding to transform dermoscopic images into temporal spike sequences that are suitable for neuromorphic processing. The experimental results demonstrate that the proposed SNN model achieves promising classification performance while offering advantages in terms of temporal encoding and energy efficiency. The model attained an overall classification accuracy of 97%, with a high F1-score of 0.98 for the nevus class. However, a slightly lower performance in the Akiec class indicates that challenges remain in accurately detecting malignant lesions. The results suggest that SNN-based systems have significant potential in skin cancer diagnostics, particularly in scenarios where real-time inference and low power consumption are crucial, such as in wearable health monitoring systems or portable diagnostic devices. Overall, this study contributes to the growing body of research on neuromorphic computing by demonstrating the applicability of biologically inspired spiking models to medical image analysis.

Keywords: Skin cancer, Spiking Neural Networks, Delta modulation, Neuromorphic computing, Lesion classification, HAM10000

EXAMINATION OF NURSES' SELF-DIRECTED LEARNING SKILLS

HEMŞİRELERİN ÖZ-YÖNETİMLİ ÖĞRENME BECERİLERİNİN İNCELENMESİ

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ÖZET

Öz yönetimli öğrenme becerisi hemşireleri yeni ve güncel bilgilere yöneltir. Böylece hemşirelik mesleği gelişir ve hasta bakım, kalitesi artar. Literatürde hemşirelerin öz yönetimli öğrenme becerilerinin incelendiği çok az çalışma bulunmaktadır. Bu sayede çalışmanın literatüre önemli bir katkısı olacaktır. Yapılan bu çalışma ile hemşirelerin öz yönetimli öğrenme becerilerinin incelenmesi amaçlanmaktadır. Bu çalışma tanımlayıcı bir çalışmadır. Çalışma 202 hemşire ile gerçekleştirildi. Veriler; Bilgi Formu ve Öz-Yönetimli Öğrenme Becerileri Ölçeği kullanılarak elde edildi. Sürekli gündüz çalışan hemşirelerin gece gündüz karışık çalışan hemşirelere göre, hemşirelik mesleğinden memnun olan hemşirelerin memnun olmayan hemşirelere göre, yabancı dil bilen hemşirelerin bilmeyen hemşirelere göre, hemşirelikle ilgili bilimsel yayın takip eden hemşirelerin takip etmeyen hemşirelere göre Öz Yönetimli Öğrenme Becerileri Ölçeği puanlarının daha yüksek olduğu belirlenmiştir. Hemşirelerin mesleki isteklerinin varlığı, hemşirelik mesleğinden memnun olmaları ve kendini geliştirmeye çalışması öz yönetimli öğrenmenin göstergesidir. Öz yönetimli öğrenme becerisi sayesinde hemşireler hem bireysel hem de mesleki bilgi, tutum, becerilerini geliştirecek ve güncelleyecektir. Böylece hasta güvenliği ve bakım kalitesi de artmış olur. Araştırmanın tek bir kurumda yapılması araştırmanın sınırlılığıdır.

Anahtar Kelimeler: Hemşire, öz yönetimli öğrenme, yaşam boyu öğrenme

DEVELOPMENT OF Ga_2O_3 FILMS GROWN ON SAPPHIRE BY RF MAGNETRON SPUTTERING METHOD AT DIFFERENT POWERS FOR UV PHOTODETECTOR APPLICATIONS

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ÖZET

Gallium oxide (Ga_2O_3) is a semiconductor that offers great potential for next-generation power electronics, solar-blind UV photodetectors, and transparent conductive electronic devices due to its wide bandgap (~4.8–5.0 eV), high electric breakdown field (~8 MV/cm), chemical stability, and high thermal resistance. In particular, the β-Ga_2O_3 phase stands out with its monoclinic crystal structure and thermodynamic stability, and it can be applied over large surface areas at low temperatures through various growth techniques.In this study, the structural and optical properties of Ga_2O_3 thin films deposited on sapphire (Al_2O_3) substrates at room temperature and under a fixed deposition time (120 minutes) were investigated. The films were grown using the RF magnetron sputtering method at different power levels (60 W, 75 W, 90 W). During the film growth, no substrate heating was applied, and all depositions were carried out under constant time and fixed gas flow conditions.The crystal structures of the deposited films were analyzed using X-ray diffraction (XRD) to evaluate the effects of different power levels on crystalline phase formation. Optical properties were characterized by UV–Vis spectroscopy, and the optical bandgap values were calculated using the Tauc method based on the transmittance spectra. The analyses revealed that, both before and after annealing, the optical bandgap generally decreased with increasing power.The results indicate that the applied power during RF magnetron sputtering at low temperature significantly influences the crystallinity and bandgap of Ga_2O_3 films. These findings are of great importance for flexible electronics and UV optoelectronic applications that require low-temperature processing.

Keywords: Ga_2O_3, RF magnetron sputtering, optical properties

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COST-BENEFIT ANALYSIS IN SMART TRANSPORTATION SYSTEM APPLICATIONS

AKILLI ULAŞIM SİSTEM UYGULAMALARINDA FAYDA-MALİYET ANALİZİ

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ABSTRACT

Akıllı ulaşım sistemleri (AUS), ulaşım altyapılarının verimliliğini artırmak, trafik güvenliğini sağlamak ve çevresel etkileri azaltmak amacıyla geliştirilen dijital teknolojilere dayalı çözümlerdir. Bu çalışmada, AUS uygulamalarının teknik ve ekonomik performansları fayda maliyet analizi yöntemi ile değerlendirilmiştir. Amerika Birleşik Devletleri'nde uygulanan adaptif trafik sinyalizasyon sistemlerinin, konvansiyonel sistemlere kıyasla %15'e varan zaman tasarrufu ve %20 oranında yakıt tüketimi azalımı sağladığı belirlenmiştir. Benzer şekilde, Hollanda'da uygulanan akıllı kavşak yönetim sistemlerinin, kaza oranlarında %30 düşüş sağladığı ve yıllık kamu sağlık harcamalarında önemli bir azalmaya neden olduğu raporlanmıştır. Çalışmada, Türkiye'de pilot olarak İstanbul'da uygulanan dinamik trafik yönetimi projeleri de analiz edilmiş; bu sistemlerin ilk yatırım maliyetlerinin yüksek olmakla birlikte, uzun vadede sağladığı çevresel ve ekonomik getirilerin bu maliyetleri karşıladığı ortaya konmuştur. Fayda maliyet analizi süreci kapsamında doğrudan maliyetler (altyapı, yazılım, bakım) ve doğrudan faydalar (zaman, yakıt, emisyon, güvenlik) nicel olarak değerlendirilmiş, net bugünkü değer ve iç verim oranı kriterleri ile AUS yatırımlarının ekonomik uygulanabilirliği analiz edilmiştir. Sonuç olarak akıllı ulaşım sistem uygulamaları, yüksek başlangıç maliyetlerine rağmen uzun vadede sosyal refahı artıran ve sürdürülebilir ulaşım hedeflerine hizmet eden yatırımlar olarak öne çıkmaktadır. Bu çalışma, karar vericilere ve mühendislik uygulayıcılarına yönelik teknik ve ekonomik bir değerlendirme çerçevesi sunmaktadır.

Keywords: Intelligent transportation systems, Cost-benefit analysis, Adaptive traffic control, Economic efficiency, Net present value

POSITION DETECTION AND DEBUGGING OF ROTOR SPEED-POSITION SENSOR CONNECTORS IN ELECTRIC VEHICLES WITH POINT-CLOUD TECHNOLOGY

ELEKTRİKLİ ARAÇLARDA ROTOR HIZ-KONUM SENSÖR KONNEKTÖRLERİNİN NOKTA-BULUT TEKNOLOJİSİ İLE KONUM TESPİTİ VE HATA AYIKLAMASI

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ÖZET

Elektrikli araçların (EV) performansında kritik rol oynayan rotor hız ve konum sensörleri, özellikle yüksek tork hassasiyeti gerektiren uygulamalarda sistem güvenilirliği açısından önem arz etmektedir. Bu çalışmada, bu sensörlere ait konnektör sistemlerinde oluşabilecek geometrik arızaların ve konumlanma hatalarının, nokta-bulut teknolojisi ile uzaktan izlenmesi, konumlandırılması ve hata ayıklanması yöntemleri incelenmiştir. Endüstri 4.0 kapsamında geliştirilen bu yaklaşımda, sensör verileri gerçek zamanlı olarak bulut platformuna aktarılmış; Amazon Web Services (AWS) üzerinden analiz edilerek hata örüntüleri makine öğrenmesi ile sınıflandırılmıştır. Aurora Vision yazılımıyla da bu hatalar mikron düzeyde piksel piksel incelenmiştir. Deneysel çalışmalarda, 20 farklı EV modelinde toplam 120 sensör konnektörü izlenmiş ve simüle edilen konnektör arızaları (kontak oksidasyonu, gevşek temas, EMI etkisi) %96.3 doğrulukla tespit edilmiştir. Nokta-bulut sistemi sayesinde, fiziksel müdahaleye gerek kalmadan hata tespiti yapılmış; bakım süresi ortalama %38 oranında azalmıştır. Ayrıca, IEEE 1451 standardına uygun olarak entegre edilen akıllı sensör arayüzleri, sistemin yeniden yapılandırılabilirliğini artırmıştır. Çalışmanın sonuçları, elektrikli araç üreticilerine arıza yönetiminde daha hızlı ve düşük maliyetli bir çözüm sunarken; aynı zamanda filo yönetimi ve otonom sürüş sistemlerinin güvenilirliğini de artırmaktadır. Bu kapsamlı yaklaşım, elektrikli araçların dijital ikiz temelli bakım stratejilerinin geliştirilmesine de olanak tanımaktadır.

Keywords: Electric vehicles, Rotor position sensor, Cloud-point technology, Fault detection, Predictive maintenance

NEW APPROACHES TO IDENTITY VERIFICATION OF CATTLE IN SMART AGRICULTURE APPLICATIONS

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ABSTRACT

The digitalization of the agricultural sector has emerged as a multidisciplinary transformation process marked by substantial investments and the convergence of various engineering disciplines. This study concentrates on cow identification systems, with particular emphasis on large-scale dairy farm operations. It explores the critical role of accurate identification in dairy cattle management, the methodologies employed for this purpose, and the challenges encountered during the implementation of autonomous identification systems on farms.

A key focus of the research is the frequent occurrence of data misattribution, where identification errors result in information pertaining to one animal being erroneously assigned to another. Such inaccuracies can significantly compromise the integrity of data-driven animal management systems. The study proposes innovative approaches to identification, particularly during the milking process, aimed at minimizing such errors. By enhancing the precision and reliability of identification technologies, the research contributes to the advancement of more effective and trustworthy herd management practices.

Identification procedures typically begin when a cow enters the milking parlor, with the first animal being associated with the first available milking unit. However, it is crucial that the cow is correctly aligned with the corresponding milking unit. Misalignment at this stage disrupts the entire sequence, leading to systematic misidentification of subsequent cows and erroneous allocation of milk production data. To address this issue, the study recommends a system wherein cows enter the milking parlor in a random sequence, and identification is autonomously and accurately confirmed only after each cow has been properly positioned within the milking unit.

The proposed approach ensures the elimination of identification order confusion and guarantees that all data are accurately associated with the corresponding animal, thereby supporting more robust and error-free livestock data management.

Keywords: Cattle Identification, Cattle Identification Reading Methods, Digital Agriculture, Smart Milking Parlor.

ELECTRONIC CIRCUIT DESIGN FOR MASTITIS DETECTION

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ABSTRACT

Mastitis is a significant disease in dairy cattle that necessitates close monitoring and timely intervention. Early diagnosis plays a critical role in the effective treatment of mastitis, as it substantially reduces both treatment costs and the risks associated with disease progression. However, conventional diagnostic approaches based on human observation and manual monitoring are often inadequate for timely detection, particularly in large-scale dairy operations.

In this context, there is a growing need for sensitive measurement systems and autonomous monitoring technologies to facilitate early diagnosis and enhance disease management. This study explores the etiology, classification, and consequences of mastitis, as well as the conventional and contemporary diagnostic methods employed in its detection. It also examines how limitations in current diagnostic techniques contribute to the delayed recognition and progression of the disease.

The findings of the study indicate that by enabling early prediction of mastitis and targeting specific animals, treatment efficacy can be significantly improved. To this end, an electronic monitoring system has been developed to collect physiological data indicative of mastitis. The system primarily analyzes electrical conductivity and color variations in milk, which are known to change in response to inflammation. Since conductivity values vary across individual animals, the electronic circuit performs real-time measurements during milking and transmits the data to a central computer via wired or wireless communication channels.

The system utilizes adaptive algorithms to establish baseline thresholds for each animal. When deviations from these thresholds are detected, the system alerts the user through smart devices (e.g., smartphones) or via audible and visual signals during milking. This approach enables proactive disease management and reduces reliance on subjective evaluation, thereby contributing to more sustainable and efficient dairy farming practices.

Keywords: Digital Agriculture, Mastitis Control, Mastitis Detection.

UPCYCLING LITHIUM-Ion BATTERY WASTE INTO HIGH-PERFORMANCE REDUCED GRAPHENE OXIDE VIA ALOE VERA-ASSISTED GREEN CHEMISTRY: ENGINEERING A CHITOSAN@EDTA@rGO HYBRID FOR RHODAMINE B ADSORPTION AND THEORETICAL INTERACTION PROFILING THROUGH DFT

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ABSTRACT

Graphene oxide (GO) was synthesized from recycled graphite using the Hummers' method and subsequently reduced via a green synthesis approach employing *Aloe vera* extract. A statistical optimization of the reduction process was conducted using Response Surface Methodology (RSM), considering temperature, extract volume, and reaction time as key factors to tailor the surface characteristics of the reduced graphene oxide (rGO). In a subsequent step, a hybrid composite material, Chitosan@EDTA@rGO, was developed through a facile synthesis route. This composite was characterized using various techniques including FTIR, XRD, BET, and SEM. Adsorption studies were performed to evaluate its potential for removing Rhodamine B (RB) dye from aqueous solutions. Additionally, Density Functional Theory (DFT) calculations were carried out to gain theoretical insights into the adsorption behavior and interaction mechanisms of the composite at the molecular level.

Keywords: Green synthesis; Reduced graphene oxide; Aloe vera; Response Surface Methodology; Chitosan@EDTA@rGO; Adsorption.

EVALUATION OF LIVER FUNCTION STATUS OF STUDENTS PREDISPOSED TO OBESITY IN MADONNA UNIVERSITY, ELELE, NIGERIA

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ABSTRACT

Obesity, particularly when characterized by the accumulation of visceral adipose tissue, has emerged as a significant global health concern. It is closely associated with increased morbidity and mortality due to its strong links with chronic diseases such as type 2 diabetes mellitus, myocardial infarction, stroke, and notably hepatic steatosis, also referred to as non-alcoholic fatty liver disease (NAFLD). These conditions often develop silently, with hepatic dysfunction being one of the earliest detectable metabolic consequences of obesity. This study is a cross-sectional observational study designed to evaluate the association between obesity and liver function among a student population.. A total of 90 subjects were assessed using standard anthropometric measurements and biochemical analyses. Data were analyzed using the chi-square test and one-way analysis of variance, with significance determined by least significant difference (LSD) post hoc testing in SPSS version 21.0. The prevalence of obesity among participants was 58.9%, with a higher occurrence among females (65.1%) compared to males (34.9%). Liver enzyme levels in obese subjects were within reference ranges, except for significant reductions ($p \leq 0.01$) in aspartate aminotransferase (AST), alkaline phosphatase (ALP), total bilirubin, and direct bilirubin compared to non-obese subjects. Notably, AST and ALP levels in non-obese participants were elevated above normal reference ranges, warranting further investigation. These findings suggest a substantial portion of the student population is at risk of obesity-related hepatic dysfunction. Preventive interventions focusing on lifestyle modification may be crucial in mitigating long-term health risks and restoring healthy body mass index (BMI) levels.

Keywords: Obesity, BMI (Body mass index), Hepatic steatosis, AST (Aspartate Aminotransferase), ALP (Alkaline Phosphatase)

ANTIOXIDANT POTENTIAL AND BIOACTIVE PROFILE OF SELECTED MILLETS: A NUTRITIONAL AND FUNCTIONAL FOOD PERSPECTIVE

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ABSTRACT

Millets are nutrient-dense cereals rich in polyphenols, flavonoids, and dietary fiber, making them ideal candidates for the development of functional foods.This study focused on the development and evaluation of a millet-based energy bar formulated with bajra *(Pennisetum glaucum)*, barnyard millet (*Echinochloa frumentacea*), and foxtail millet (*Setaria italica*), aiming to create a nutrient-dense, antioxidant-rich snack. The formulation incorporated natural sweeteners such as honey and dates, along with nuts and seeds to enhance nutritional value and sensory appeal. *(Pennisetum glaucum*), barnyard (*Echinochloa frumentacea*) and Foxtail (Seteria italica); Powder incorporate with standard bar formulation at varying concentrations (10% ,20% and 30%) was supplement with dates for making bar. The resulting bar were evaluated for their physicochemical properties, sensory attributes and antioxidant activity. The obtained result from the study that the different concentration improved the antioxidant activity from 249.65 mm AAE/g to 505.09 mm AAE/g. The TPC, TFC, DPPH and FRAP of the prepared muffin were determined and progressively increased with increasing formulation. Analysis of FTIR is examine for the presence of functional compounds in prepared bar .Sensory evaluation indicates that different millet-based bar is acceptable in different concentration . The study concludes that millet-based energy bars are a viable option for developing functional, gluten-free snacks that support nutritional security and sustainable food practices. Also demonstrates the feasibility of using millets as a base for developing functional snack bars aimed at enhancing dietary antioxidant intake and preventing oxidative stress-related disorders.

Keywords: Millet; Bajra (*Pennisetum glaucum),* barnyard *(Echinochloa esculenta*) and Foxtail (*Seteria italica*) Powder; Bar; Antioxidant

Citrus pseudolimon PEEL INCORPORATED MUFFIN: EFFECT ON THE PHYTOCHEMICAL AND SENSORIAL PROPERTIES OF MUFFIN

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ABSTRACT

Citrus pseudolimon (Galgal) is an underutilized citrus fruit native to India, with significant potential in the food application. Citrus pseudolimon peel is a byproduct obtained from primary processing and is usually discarded as waste. This study focuses on the development of muffins incorporated with *Citrus pseudolimon* (Galgal) peel powder, a byproduct abundant in phytochemicals such as flavonoids, carotenoids, essential oils, dietary fiber, and vitamin C. Incorporating *Citrus pseudolimon* (CP) peel powder into muffin formulations not only enhances the nutritional profile but also improves the antioxidant properties of the muffin. Citrus pseudolimon peel powder was tested prepared from its peels which were cleaned, dried using hot air oven, and tested for chemical composition and phytochemical properties. CP powder at different concentrations (0, 2, 4, 6, 8%) was supplemented with refined wheat flour for making muffin and evaluated for its phytochemical properties. Results revealed that the antioxidant activity improved from 210.14 mm AAE/g to 273.92 mm AAE/g (at 8% level). The TPC (57.76mg GAE/g- 66.86mg GAE/g), TFC (16.61mg QE/g-27.82mg QE/g), DPPH (44.17%-50.16%) and FRAP (1.112mg TE/g-2.228mg TE/g) of the prepared muffin were determined and progressively increased with increasing *Citrus pseudolimon* peel incorporation. Presence of characteristics peak in FTIR spectra with a range between 500 to 4000 cm^{-1} confirms the presence of functional compounds in the muffin. Sensory analysis showed that incorporating peel powder affected the overall acceptability of muffins. Among all formulations, the muffin with 4% peel powder achieved the highest overall acceptability score of 8.2. Thus, CP peel flour shows strong potential for enhancing the nutritional and quality attributes of muffins.

Keywords: *Citrus pseudolimon* peel powder; Antioxidant; Muffin

MUFFIN DEVELOPMENT WITH CITRUS JAMBHIRI PEEL POWDER INCORPORATION

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ABSTRACT

Citrus × *jambhiri*, commonly known as rough lemon, is an underutilized citrus species cultivated in various regions of Asia. The fruit contains flavonoids such as hesperidin and naringin, which are known for their anti-inflammatory, antioxidant, and heart-protective properties. Citrus by-products are the leftover materials produced after juice extraction, making up about 50% of the fruit's total weight. Among them, the peel is often considered waste and poses a disposal problem. This study focuses on the peel waste that is incorporated into muffin formulations as a functional food product, enhancing nutritional value while addressing the issue of citrus peel waste. The muffins showed increased levels of dietary fibre and antioxidants, promoting sustainability and potential health benefits. *Citrus jambhiri* powder was tested for prepared from peel which are cleaned and dried in oven. Peels were incorporated into standard muffin formulations at varying concentrations (0%, 2%, 4%, 6% and 8%) was supplemented with refine wheat flour for making muffin. The resulting muffins were evaluated for their physicochemical properties, sensory attributes and antioxidant activity. The obtained result from the study that the different concentration improved the antioxidant activity from 71.2 mm AAE/g to 157.4 mm AAE/g. The TPC, TFC, DPPH and FRAP of the prepared muffin were determined and progressively increased with increasing formulation. Analysis of FTIR is examine for the presence of functional compounds in prepared muffin. Sensory evaluation revealed favourable consumer acceptance for muffin is 2%. *Citrus jambhiri* peel as a functional ingredient in baked goods, aligning with current trends in sustainable food innovation and functional nutrition. Developed muffins using citrus peel to address a research gap, highlighting the potential of citrus peel as a value-added ingredient that enhances the nutritional quality of baked products while promoting sustainable food practices.

Keywords: *Citrus jambhiri* peel powder; Muffin; Antioxidant

OPTIMIZATION OF ULTRASOUND-ASSISTED EXTRACTION (UAE) OF POLYPHENOLS FROM BROWNTOP MILLET FLOUR USING RESPONSE SURFACE METHODOLOGY (RSM)

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ABSTRACT

In recent years, browntop millet (*Brachiaria ramosa*) has grown in popularity due to its exceptional nutritional value and associated health benefits. The proximate analysis of flour shows high percentage carbohydrate (70.32%) followed by protein (9.95 ± 0.15%), fat (6.53 ± 0.25%), crude fiber (1.93 ± 0.10. Browntop millet contains a significant amount of polyphenolic compounds, which can be effectively extracted using ultrasound-assisted extraction (UAE). In this study, the extraction conditions were optimized using Response Surface Methodology (RSM). Based on preliminary experiments, solvent concentration, extraction duration, and sample-to-solvent ratio were selected as the key variables. The optimized conditions identified were 50% methanol, 57 minutes of extraction duration, and a sample-to-solvent ratio of 27 ml (w/v) and demonstrated total antioxidant activity (TAA) 494.41 mmol AAE/g Total phenolic content (TPC) values were 4.45 mg GAE/g, while total flavonoid content (TFC) 4.40 mg QE/g. Free radical scavenging assays revealed 54.47% DPPH inhibition and 39.04% nitric oxide inhibition. The energy bar was formulated with 20% browntop millet flour (w/w) and compared to a control. Antioxidant profiling demonstrated the fortified bar exhibited significantly enhanced TAA (1963.13 ± 9.36 mmol AAE/g) compared to the control (1904.27 ± 3.61 mmol AAE/g). Similarly, TPC (6.11 ± 0.09 mg GAE/g vs. 6.49 ± 0.05 mg GAE/g) and TFC (19.43 ± 0.03 mg QE/g vs. 18.64 ± 0.30 mg QE/g) indicated improved bioactive retention. These findings underscore the potential of browntop millet flour as a functional ingredient to enhance the nutritional and antioxidant profile of various food products.

Keywords: browntop. Millet. Polyphenol. UAE.

FORMULATION AND FUNCTIONAL EVALUATION OF SPINACH-ENRICHED GLUTEN-FREE CRACKERS FROM BUCKWHEAT AND RICE FLOUR BLENDS

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ABSTRACT

The growing demand for gluten-free products has led to increasing interest in nutrient-dense and functionally enhanced alternatives to conventional snacks. This study focused on the development of gluten-free crackers using a composite flour blend consisting of 60% buckwheat and 40% rice flour, enriched with spinach powder at four levels: 0%, 6%, 8%, and 10%. Buckwheat and rice flour serve as gluten-free bases with good nutritional profiles, while spinach was incorporated to boost the crackers' fiber, protein, and antioxidant content. Functional property analysis of the flour blends showed a positive correlation between spinach concentration and hydration characteristics, with water absorption capacity increasing from 1.84 to 2.50 g/g, and oil absorption index rising from 1.02 to 1.24 g/g. Proximate composition revealed enhanced protein (from 7.54% to 8.97%) and fiber (from 3.81% to 4.46%) contents in the spinach-enriched crackers, along with reductions in moisture and carbohydrate levels. Physical parameters, such as increased bulk density and reduced cooking loss, indicated improved structural integrity. Antioxidant activity, measured across formulations, increased proportionally with spinach addition, confirming its functional contribution. FTIR spectroscopy confirmed the successful integration of spinach-derived functional groups into the cracker matrix. Sensory evaluation demonstrated that the 6% spinach formulation received the highest overall acceptability score, particularly in color, aroma, and taste. These findings highlight the potential of spinach-fortified buckwheat–rice flour blends in creating gluten-free crackers that are not only nutritionally superior but also sensory-appealing. Such formulations offer a promising avenue for functional food development tailored to health-conscious and gluten-sensitive populations.

Keywords: Gluten-free crackers; buckwheat flour; rice flour; spinach powder; functional properties; antioxidant activity; sensory quality.

REDEFINING MEDICAL MICROBIOLOGY: THE EMERGING ROLE OF NANOBIOTECHNOLOGY

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ABSTRACT

Nanobiotechnology, an interdisciplinary field at the intersection of nanotechnology and biotechnology, is redefining the landscape of medical microbiology by harnessing the unique properties of nanoscale materials to address complex microbial challenges. This study critically examines the evolution and application of nanobiotechnology in medical microbiology, highlighting its pivotal role in advancing diagnostic precision, therapeutic efficacy, and innovative vaccine development. Recent literature and case studies reveal that nanoscale biosensors and imaging agents, such as quantum dots and magnetic nanoparticles, have significantly enhanced the sensitivity, speed, and accuracy of pathogen detection, enabling early diagnosis and timely intervention in clinical practice. In therapeutics, engineered nanoparticles facilitate highly targeted drug delivery, improving bioavailability and minimizing side effects, while certain nanomaterials exhibit intrinsic antimicrobial properties that offer promising solutions against antibiotic-resistant pathogens. The integration of nanotechnology into vaccinology has also ushered in a new era of immunization, with nano-carriers enabling controlled antigen delivery and robust immune responses, thus addressing longstanding challenges in vaccine design for complex and emerging infectious diseases. While these advancements offer clear advantages over traditional methods, including higher specificity, reduced side effects, and rapid response, challenges remain regarding scalability, regulatory oversight, and long-term safety. In conclusion, nanobiotechnology stands as a transformative force in medical microbiology, offering innovative solutions for diagnostics, therapeutics, and immunization that can significantly enhance global health outcomes. It is recommended that future efforts prioritize interdisciplinary research, robust regulatory frameworks, and international collaboration to ensure the safe, effective, and equitable adoption of nanobiotechnological innovations in medical microbiology worldwide.

NEUROINFLAMMATION AS A KEY MECHANISM IN NEUROLOGICAL DISEASES

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ABSTRACT

Neuroinflammation has emerged as a critical pathophysiological mechanism in the development and progression of numerous neurological diseases, including neurodegenerative disorders such as Alzheimer's disease (AD), Parkinson's disease (PD), multiple sclerosis (MS), and amyotrophic lateral sclerosis (ALS), as well as acute conditions like stroke and traumatic brain injury (TBI). It involves the activation of the brain's resident immune cells, particularly microglia and astrocytes, which release pro-inflammatory cytokines, chemokines, reactive oxygen species (ROS), and other inflammatory mediators in response to injury, infection, or disease. While this inflammatory response is initially protective, chronic or excessive neuroinflammation leads to neuronal dysfunction, synaptic loss, and neuronal death, driving disease progression. Key signaling pathways, including the activation of cytokines such as TNF-α, IL-1β, and IL-6, play a central role in sustaining the inflammatory environment and exacerbating neuronal damage. This article reviews the current understanding of neuroinflammation's role in neurological diseases and highlights emerging therapeutic strategies aimed at modulating the inflammatory response. Targeting neuroinflammation presents a promising approach to slowing disease progression and improving outcomes for patients with these debilitating conditions. However, balancing the beneficial and harmful effects of inflammation remains a significant challenge, requiring precise modulation of immune responses within the brain.

Keywords: neuroinflammation, neurodegenerative diseases, microglia, cytokines, neuronal dysfunction

OVERVIEW ON URINARY TRACT INFECTION

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ABSTRACT

Urinary Tract Infection (UTI) is a common bacterial infection affecting any part of the urinary system, including the kidneys, ureters, bladder, and urethra. UTIs are more prevalent in females due to anatomical and physiological differences, although they can affect individuals of all ages and genders. The most frequent causative agent is Escherichia coli, a bacterium normally found in the gastrointestinal tract. Symptoms of UTIs vary depending on the site of infection but commonly include dysuria, increased urinary frequency, urgency, and lower abdominal discomfort. Diagnosis is typically confirmed through urinalysis and urine culture. Treatment primarily involves antibiotics, with the choice depending on the severity and resistance patterns. Recurrent infections may necessitate further investigation to identify underlying causes. Preventive strategies, including proper hygiene, adequate hydration, and in some cases, prophylactic antibiotics, are important in reducing incidence. Understanding the pathogenesis, risk factors, and management of UTIs is crucial for effective treatment and prevention, particularly in populations at higher risk.

STRATEGIC NARRATIVES: HOW MEDIA INFLUENCES FOREIGN POLICY DECISIONS IN GLOBAL POWER STRUGGLES

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ABSTRACT

In the current international system, the media plays an important role in determining global powers' foreign policy by influencing public opinion, framing political debates, and directing diplomatic decision-making. This study critically investigates the strategic use of media narratives in international relations, using fundamental theoretical frameworks such as agenda-setting, framing theory, and the idea of soft power. The research tries to explore how media serves not just as a mirror of political events, but also as a strong instrument used by governments and political players to shape reality, organize support, and achieve geopolitical goals.

The study employs a case-based approach, focusing on high-profile contemporary geopolitical developments such as the Russia-Ukraine conflict and US-China relations, to show how governments, state-affiliated media outlets, and political leaders use both traditional and digital media to influence international perceptions and strategic outcomes. These case studies demonstrate the complex interplay between media management, propaganda, public diplomacy, and international image-building in today's multipolar world.

Furthermore, the study highlights the expanding ethical problems that journalists confront while reporting on global events in an age of digital disinformation, algorithmic prejudice, and increased state power over media platforms. It critically examines the relationship between objective reporting and political pressure, emphasizing questions about media independence, narrative manipulation, and public confidence in global contexts.

By investigating the interaction of media and foreign policy, this study adds to a better understanding of how communication techniques influence global power dynamics. The findings are useful for politicians, media workers, and researchers as they navigate the changing terrain of political communication in the twenty-first century. (Entman, 2004; Nye, 2004).

Keywords: Strategic Narratives, Foreign Policy, Media Influence, Soft Power, Geopolitical Communication, Disinformation, Digital Media, Propaganda, International Journalism, Public Opinion, Cyber Warfare

1. *Projections of Power*. (n.d.-j).

SOCIAL MEDIA'S ROLE IN INTERNATIONAL CRISES: A STRATEGIC TOOL FOR INFLUENCE, PERCEPTION MANAGEMENT, AND CRISIS DIPLOMACY (2015-2025)

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ABSTRACT

Social media has emerged as a transformational force in international crises, altering how governments communicate, build narratives, and wield power on a global scale. This article looks at how major nations including the United States, Russia, and China used social media platforms strategically between 2015 and 2025 to achieve their geopolitical goals. Using a qualitative methodology, the research examines key case studies such as the Russia-Ukraine war (7), US-China trade disputes (2), and Middle Eastern geopolitical concerns (9). These instances demonstrate how social media has been used for a variety of objectives, including propaganda distribution, misinformation operations, public diplomacy, and narrative control.

The results show that social media is a strategic tool of influence as well as a route for communication, allowing governments to project soft power, participate in information warfare, and shape public opinion. The study also looks at the moral dilemmas raised by state-sponsored propaganda, digital distortion, and disinformation on social media. For politicians, media professionals, and academics seeking to negotiate the intricate nexus of digital communication and foreign diplomacy, this research delivers insightful information by offering a thorough examination of social media's involvement in international crises. (8)

Keywords: Social Media, international journalism, Media, International Crises, Public Diplomacy, Strategic Communication, Disinformation, Propaganda, Crisis Diplomacy, Media Strategies.

RESOURCE DEVELOPMENT AND MANAGEMENT: DARAGA COMMUNITY COLLEGE EXPERIENCE

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ABSTRACT

Resource development and management is one of the crucial processes in the education institution for assuring quality especially in higher education. This is also the same with community colleges. The main objective of this study was to determine the experiences of stakeholders on resource development and management of Daraga Community College. Specifically, this study answered the status of resources, the practices and the strengths, weaknesses, opportunities and threats in the school resource development and management as experienced by the stakeholders. The researchers utilized case study method. The data were gathered from 35 internal and external stakeholders as key informants in the study composed of instructors, administrators, non-teaching staffs, and members of Board of Trustees. The needed data were determined through document analysis, interviews and SWOT analysis. The major findings in terms of the status of Daraga Community College where resources are considered available but need to be improved in order to serve the large number of enrollees in the college. There are certain practices of resource development and management which are done by the stakeholders in the college. It was also found that the college has strengths, weaknesses, opportunities and threats in resource development and management. To address the concerns in the experiences of the stakeholders in the college, the researcher proposed a management model in resource development and management which is called as 4S Management Model. The management model aims to create and define the capacity capabilities of Daraga Community College to deliver quality and accessible education to Darageños.

FOUNDATIONS AND CONCEPTUAL MODELS OF TAXPAYER TAX COMPLIANCE

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ABSTRACT

This work delves into the significance of tax compliance for small and medium-sized enterprises (SMEs) and its vital role in driving both economic and social development. It starts by explaining the key components of tax compliance, emphasizing that it extends beyond just filing tax returns to encompass transparency and adherence to legal obligations. The article employs several theoretical models—voluntary, coercive, conditional, and reactive—to analyze the factors influencing SMEs' tax behavior. Each model is explored through the lens of psychological, social, economic, and institutional elements that affect firms' decisions to comply or not with tax regulations. Additionally, international case studies are incorporated, comparing experiences from both developed and developing nations to uncover best practices and persistent challenges in enhancing tax compliance. The article concludes with practical recommendations aimed at building trust between tax authorities and SMEs, simplifying tax systems, and balancing incentives and penalties effectively. Through a comprehensive understanding of tax compliance, this article contributes to shaping policies that support SME growth and competitiveness, while ensuring the integrity and stability of national tax systems.

Keywords: Tax compliance, SMEs, Economic development, Conceptual models, Tax policies

ASSESSMENT OF FACTORS INFLUENCING ACCESS TO RESIDENTIAL LAND IN TYPICAL URBAN BORDER COMMUNITIES OF NIGERIA: A GENDER DIMENSION

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ABSTRACT

The study attempts to examine the factors influencing access to residential land among men and women in Ogun State border communities, Nigeria. A multi-stage sampling technique was used in the selection of 411 homeowners. Frequency distribution, percentages, factor analysis, binary probit regression, and correlation were used to analyse the data that were elicited from men and women homeowners. The study reveals that affordability, land availability, procedural, security of tenure, and personal factors were associated with access to residential land among men while affordability, land availability, security of tenure, personal, and procedural were the factors associated with access to residential land among women, based on their order of importance. The use of binary probit regression analysis shows that the extracted factors significantly influenced secure access to residential land among men and women. Findings from the correlation analysis show that access to residential lands is associated with the personal attributes of men and women. It was further observed that these personal attributes varied among men and women in the study area. The study concluded that access to residential land is attributed to different factors, and these factors vary among men and women. The study suggested that the government and traditional institutions should consider these factors in ensuring easy access to residential land among men and women in the study area.

Keywords: Residential land; Access to land; Housing; Gender; Border communities,

A CAREER PROGRAM TO ENHANCE CAREER COMPETENCE, CAREER OPTIMISM AND ADAPTABILITY IN THE TRANSITION FROM UNIVERSITY TO WORK

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ABSTRACT

The aim of this study is to create a career program for engineering students to improve their career competencies during the transition from university to work, to facilitate their adaptation to business life and to make them more optimistic about the future and to evaluate the effectiveness of the program. In this action research study, semi-structured interviews were conducted with engineering faculty students, career counselors and human resources experts through snowball sampling to discover the needs of students during the transition to work. The interviews were analyzed in MAXQDA program. The results of the thematic analysis revealed that for the program, both activities that can be implemented by career counselors and practices that can provide experience transfer to students by people working in the field are needed. In the sessions with activities that can be done by the career counselor, practices such as swot analysis, creating career options, making a career plan, and rehearsing a job interview were conducted. In the field-oriented sessions, there were technical trips that allowed students to see different working environments and a panel discussion with speakers and alumni from different sectors. In the creation of the content of the career program, in addition to the themes reached by the researchers, career structuring theory was also used. The results of the thematic analysis revealed that both activities that can be implemented by career counselors and practices that can provide experience transfer to students by people working in the field are needed for the program. The career program consisted of eight sessions. Eleven 3rd and 4th year engineering faculty students who scored low on the Career Competence Scale and Career Adaptability and Optimism Scale participated in the program. SPSS program and student feedbacks were used to evaluate the effectiveness of the program. As a result of the comparison of the pre-test and post-test mean scores of the students in the SPSS program, it was concluded that the program helped to improve the career competencies, career adaptability and optimism of the students during the transition to work. In addition, the forms in which open-ended questions were sent to the students during the program and the questions asked in the evaluation session, which was the last session, also revealed that the program contributed to the students.

Keywords: Career competence, career adaptation, career optimism, transition from university to work, action research.

EXAMINING the ERGONOMICS, VISUAL and COMMUNICATION ELEMENTS of KINDERGARTEN CLASSES

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ABSTRACT

This study aimed to develop a scale for evaluating kindergarten classroom designs in terms of ergonomics, visual, and communicative elements. The scale development process began with a literature review, followed by the creation of a 40-item pool based on indicators related to the ergonomics, visual, and communication aspects of kindergarten environments. The initial item pool was revised with feedback from two administrators and two preschool teachers holding relevant expertise. For content validity, the draft scale was evaluated by two experts in early childhood education, two in design, and two in measurement and evaluation. A binary rating system (appropriate/inappropriate) was used, and experts were asked to provide suggestions for any item deemed inappropriate. During this process, items were assessed for their relevance to kindergarten categories, clarity of expression, and linguistic appropriateness. Based on expert feedback, wording revisions were made and six items were removed from the scale. The final version of the scale consisted of 34 items, rated on a 5-point Likert scale: strongly agree (4) to strongly disagree (0). A pilot study was conducted in the first semester of the 2024–2025 academic year with 200 voluntary preschool teachers from public early childhood institutions in Ankara, Turkey. Data analysis yielded a KMO value of 0.93 and a significant Bartlett's test ($p<0.00$), indicating the suitability for factor analysis. Results revealed two dimensions: "visual and ergonomic elements" (23 items, factor loadings ranging from 0.58 to 0.88, explaining 38.55% of the variance) and "communication" (10 items, factor loadings from 0.48 to 0.95, explaining 16.30% of the variance). The total variance explained was 58.77%. The reliability of the scale was determined using Cronbach's alpha, calculated as 0.94, indicating a high level of internal consistency for the final 33-item, two-factor scale.

Keywords: ergonomics, preschool, communication, design

***** This paper was produced from the master's thesis titled "Analysis of Interior Designs in Preschool Education Institutions in Terms of Ergonomics, Visual and Communication Elements", which is ongoing by the first author, who is a student at the Department of Visual Communication Design, Department of Art and Design, Institute of Social Sciences, Ankara Yıldırım Beyazıt University, under the supervision of the second author.

EVALUATION OF THE RELATIONSHIPS BETWEEN SELF DIFFERENTIATION, PARENTAL ATTITUDES, AND PSYCHOLOGICAL RESILIENCE

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ABSTRACT

Self-differentiation is one of the basic concepts of M. Bowen's family systems theory. People with a high level of self-differentiation can have healthy relationships. This study evaluates the relationships between self-differentiation, parenting attitudes, and psychological resilience. Some studies have demonstrated significant relationships between self-differentiation and the other mentioned concepts. However, the number of those studies is quite limited, especially in Turkey. Therefore, it is anticipated that this research would fill some gaps in the literature. 359 adults aged 18 years or older participated in this study. Data were collected online based on voluntariness and accessibility. The data collection instruments included the Short Form of the Differentiation of Self Inventory, the Brief Resilience Scale, the Parenting Attitude Scale, the Shortened Perceived Parental Attitudes Scale — Child Form, and the Demographic Information Form. Maternal and paternal attitudes were assessed separately across three dimensions: interest/love/acceptance, strict control, and rejection. Compatible with our expectations, the findings revealed that self-differentiation was positively correlated with positive (interest/love/acceptance) maternal and paternal attitudes and psychological resilience *(r* = 0.204, 0.199, 0.581, respectively; $p < .01$) and negatively correlated with negative parental attitudes (rejection and strict control) *(r* = –0.347, –0.313, –0.241, –0.257, respectively; $p < .01$). The results of the multiple linear regression analysis showed that self-differentiation was significantly predicted by psychological resilience and negative maternal attitudes ($F(3, 355) = 76.499$, $p < .001$; *Adjusted* $R^2 = 0.39$). Incompatible with our expectations, it was found that other maternal and paternal attitudes were not significant predictors of self-differentiation ($p > .05$). One of the most important findings of this study is that psychological resilience was found to be a stronger predictor of self-differentiation, even than maternal attitudes. It was recommended that future programs to improve personality development and relationship quality should focus more on strengthening individuals' psychological resilience.

Keywords: *Differentiation of Self, Psychological Resilience, Parental Attitudes*

BENLİK FARKLILAŞMASI, EBEVEYN TUTUMLARI VE PSİKOLOJİK DAYANIKLILIK ARASINDAKİ İLİŞKİLERİN İNCELENMESİ

ÖZET

Benlik farklılaşması, M. Bowen'ın aile sistemleri teorisinin temel kavramlarından birisidir. Benlik farklılaşması yüksek bireyler sağlıklı ilişkiler yürütebilirler. Bu araştırmanın amacı benlik farklılaşması ile ebeveyn tutumları ve psikolojik sağlamlık arasındaki ilişkileri incelemektir. Benlik farklılaşması ile bu kavramlar arasında ilişki olduğunu bulan araştırmalar olmakla birlikte, özellikle Türkiye'de bu araştırmalar sınırlı sayıdadır. Bu kapsamda araştırmamızın alan yazına katkı sağlayacağı düşünülmüştür. Araştırmaya 18 yaş ve üzeri 359 yetişkin katılmış, veriler çevrimiçi olarak gönüllülük ve ulaşılabilirlik esasına göre toplanmıştır. Veri toplamada, Benliğin Farklılaşması Ölçeği Kısa Formu, Kısa Psikolojik Sağlamlık Ölçeği, Çocuk Yetiştirme Stilleri Ölçeği, Kısaltılmış Algılanan Ebeveyn Tutumları Ölçeği – Çocuk Formu ve Demografik Bilgi Formu kullanılmıştır. Anne ve baba tutumları ayrı ayrı ve üç boyut (ilgi/sevgi/kabul, sıkı denetim/kontrol ve reddedicilik) üzerinden incelenmiştir. Araştırma sonuçları, beklentilerimizle uyumlu şekilde, benlik farklılaşmasının olumlu anne ve baba tutumları ve psikolojik sağlamlık ile pozitif (sırası ile r = 0,204, 0,199, 0,581, p < 0,01, olumsuz (reddecilik ve sıkı denetim/kontrol) anne ve baba tutumları ile ise negatif ilişkili (sırası ile r = –0,347, -0,313, -0,241, -0,257, p < 0,01) olduğunu göstermiştir. Çoklu doğrusal regresyon analizi sonuçları ise benlik farklılaşmasının psikolojik sağlamlık ve olumsuz anne tutumları tarafından anlamlı şekilde yordandığını (F(3, 355) = 76,499, p < .001; $R^2düz = 0,39$). ortaya koymuştur. Beklentilerimiz ile uyumsuz olarak, diğer anne ve baba tutumlarının ise benlik farklılaşmasının anlamlı yordayıcıları olmadığı (p> .05) tespit edilmiştir. Araştırma sonuçları arasında, psikolojik sağlamlığın, anne tutumlarından bile daha güçlü bir yordayıcı olduğunun belirlenmesi özellikle dikkat çekicidir. Gelecekte kişilik yapılanmasına ve kişilerarası ilişkilere yönelik önleyici ve koruyucu çalışmalarda, bireyin psikolojik dayanıklılığını güçlendirmeye odaklanan müdahalelerin artırılması önerilmektedir.

Anahtar Sözcükler: Benlik farklılaşması, Psikolojik sağlamlık, Ebeveyn tutumları.

EXTENDED ABSTRACT

Introduction and Objectives: The purpose of this study is to explore the correlational and predictive relationships between self-differentiation, parenting attitudes, and psychological resilience, with special consideration to differentiation of self, which is a key concept within the framework of Murray Bowen's family systems theory. Individuals with a high level of self-differentiation would possess a healthy personality formation and can deeply and lovingly attach to others. At the same time, they would preserve their personal boundaries and be able to maintain these relationships over time. This also implies that people with low self-differentiation are likely to show several personality disorder dispositions that tend to worsen social interactions and relationships. The body of research regarding parenting practices, psychological resilience, and self-differentiation is rather sparse, especially in Turkey. It is anticipated that this research would fill some gaps in the literature.

Methods: The sample for this study consisted of 359 individuals who were 18 years old and over. The data was gathered online while observing the principle of voluntary participation and accessibility. The following instruments were used for data collection: The Short Form of the Differentiation of Self Inventory, the Brief Resilience Scale, the Parenting Style Scale, the Shortened Perceived Parental Attitudes Scale – Child Form, and a Demographic questionnaire. Maternal and paternal attitudes were assessed separately across three dimensions: interest/love/acceptance, rejection, and strict control.

Results: Compatible with our expectations, results revealed that self- differentiation had a positive and significant correlation with maternal interest/love/acceptance (r = 0.204, p < .01), paternal interest/love/acceptance attitudes (r = 0.199, p < .01), and psychological resilience (r = 0.581, p < .01) whereas negative and significant correlations were found between self - differentiation and maternal rejection (r = -0.347, p < .01), paternal rejection (r = -0.313, p < .01), maternal strict control (r = -0.241, p < .01), and paternal strict control attitudes(r = -0.257, p < .01).

The multiple linear regression analysis results yielded a significant model and showed that approximately 39% of the total variance of self-differentiation was explained by psychological resilience, maternal rejection, and maternal strict control attitudes ($F(3, 355) = 76.499$, $p < .001$; *Adjusted* R^2 = 0.39). This model showed that controlling the other predictors, psychological resilience alone explained 26.8% ($\beta = 0.536$, $t(355) = 12.53$, $p < .001$, %95 CI [1.444, 1.981], part $r = .518$.), maternal rejection 1.4% ($\beta = –0.147$, $t(355) = –2.88$, $p = .004$, %95 CI [–0.818, –0.155], part $r = –.119$.), and maternal strict control attitudes 1.0% ($\beta = –0.125$, $t(355) = –2.51$, $p = .012$, %95 GA [–0.363, –0.044], part $r = –.104$.) of the total variance of self-differentiation However, incompatible with our expectations, it was found that other maternal and paternal attitudes were not significant predictors of self-differentiation (p > .05).

Discussion and Conclusion: The results of this study revealed that self-differentiation correlated with psychological resilience and parental attitudes. Furthermore, the findings showed that psychological resilience and negative maternal attitudes were significant predictors of self-differentiation. The most highlighted finding was that psychological resilience was a stronger predictor than maternal attitudes, which the literature considers fundamental for personality development. Based on this, it is recommended that future preventive and protective interventions regarding personality development and social functioning focus more on enhancing psychological resilience. In the present study, the majority of the participants were female (63.5%), single (77.2%), and had a bachelor's degree or higher (87.5%), which presents a limitation in terms of the generalizability of our findings.

Keywords: *Differentiation of Self, Psychological Resilience, Parental Attitudes*

TAM ÖZET

Giriş ve Amaç: Bu araştırma, Murray Bowen'ın aile sistemleri teorisinin temel kavramlarından biri olan benlik farklılaşması ile ebeveyn tutumları ve psikolojik sağlamlık arasındaki korelasyonel ve yordayıcı ilişkileri incelemek amacıyla yürütülmüştür. Benlik farklılaşması yüksek bireyler, sağlıklı bir kişilik yapılanmasına sahip olmakta, sınırlarını koruyabildikleri sevgi dolu derin ilişkiler kurabilmekte ve bu ilişkileri sürdürebilmektedirler. Söz konusu durum, benlik farklılaşması düşük bireylerin, kişilerarası ilişkiler alanında işlevsellik kaybına neden olan çeşitli kişilik bozukluğu eğilimlerine de sahip olabileceklerine işaret etmektedir. Ebeveyn tutumları, psikolojik sağlamlık ve benlik farklılaşması üzerine yapılan çalışmalar özellikle Türkiye'de sınırlı sayıdadır. Söz konusu ilişkilerin kapsamlı bir şekilde ele alınmasının alan yazın açısından önemli olduğu düşünülmüştür.

Yöntem: Araştırmaya, 18 yaş ve üzeri 359 yetişkin katılmıştır. Veriler çevrimiçi ortamda, gönüllülük ve ulaşılabilirlik esasına göre toplanmıştır. Araştırmada veri toplama aracı olarak; Benliğin Farklılaşması Ölçeği Kısa Formu, Kısa Psikolojik Sağlamlık Ölçeği, Çocuk Yetiştirme Stilleri Ölçeği, Kısaltılmış Algılanan Ebeveyn Tutumları Ölçeği – Çocuk Formu ve Demografik Bilgi Formu kullanılmıştır. Anne ve baba tutumları ayrı ayrı ve üç boyut (ilgi/sevgi/kabul, reddedicilik, sıkı denetim/kontrol) üzerinden değerlendirilmiştir.

Bulgular: Araştırma değişkenleri arasındaki ilişkilerin incelendiği korelasyon analizi sonuçlarına göre beklentilerimize paralel şekilde, benlik farklılaşması ile anne kabul/ilgi/sevgi (r = 0,204, p < 0,01), baba kabul/ilgi/sevgi (r = 0,199, p < 0,01) tutumları ve psikolojik sağlamlık (r = 0,581, p < 0,01) arasında pozitif yönde anlamlı; anne reddedicilik (r = –0,347, p < 0,01), baba reddedicilik (r = –0,313, p < 0,01), anne sıkı denetim/kontrol (r = –0,241, p < 0,01) ve baba sıkı denetim/kontrol (r = –0,257, p < 0,01) tutumları arasında ise negatif yönde anlamlı ilişkiler olduğu görülmüştür.

Çoklu Doğrusal Regresyon Analizi sonuçları ise beklentimizle kısmen örtüşmüştür. Yapılan analiz sonucunda; benlik farklılaşmasına ilişkin toplam varyansın yaklaşık %39'unun psikolojik sağlamlık, anne reddedicilik ve anne sıkı denetim/kontrol tutumları tarafından açıklandığı (F(3, 355) = 76,499, p < .001; $R^2düz$ = *0,39*). tespit edilmiştir. Diğer değişkenler sabit tutulduğunda, tek başına psikolojik sağlamlık, annenin reddedici tutumları ve annenin sıkı denetim/kontrol tutumları sırası ile benlik farklılaşması toplam varyansının %26,8 (β = 0.536, t(355) = 12.53, p < .001, %95 GA [1.444, 1.981], kısmi r = .518.), %1,4 (β = –0.147, t(355) = –2.88, p = .004, %95 GA [–0.818, –0.155], kısmi r = –.119.) ve %1 (β = –0.125, t(355) = –2.51, p = .012, %95 GA [–0.363, –0.044], part r = –.104.)'ini açıklamaktadır. Buna karşın, beklentilerimiz ile uyumsuz olarak diğer anne ve baba tutumlarının benlik farklılaşmasının anlamlı yordayıcıları olmadığı bulunmuştur (p> .05).

Tartışma ve Sonuç: Araştırma, psikolojik sağlamlık ve ebeveyn tutumlarının benlik farklılaşması ile ilişkili olduğunu ve psikolojik sağlamlık ile olumsuz anne tutumlarının benlik farklılaşmasını anlamlı şekilde yordadığını göstermiştir. Psikolojik sağlamlığın, alan yazında kişilik yapılanmasının en güçlü belirleyicilerinden biri olarak belirtilen anne tutumlarından bile daha güçlü bir yordayıcı olduğunun belirlenmesi özellikle dikkat çekicidir. Gelecekte kişilik yapılanmasına ve kişilerarası ilişkilere yönelik önleyici ve koruyucu çalışmalarda, bireyin psikolojik dayanıklılığını güçlendirmeye odaklanan müdahalelerin arttırılması önerilmektedir. Katılımcılarımızın %63,5'i kadın, %77,2'si bekar olup %87,5'i lisans ve üstü eğitim seviyesine sahiptir. Söz konusu durum, araştırma bulgularımızın genelleştirilmesine ilişkin bir kısıtlılık oluşturmaktadır

Anahtar Sözcükler: benlik farklılaşması, psikolojik sağlamlık, ebeveyn tutumları.

EVALUATION OF THE RELATIONSHIP BETWEEN BODY SATISFACTION AND SOCIAL MEDIA UNCONSCIOUSNESS IN THE CONTEXT OF HIJAB AND POTENTIAL PROTECTIVE FACTORS

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ABSTRACT

This study explored the relationship of body satisfaction with social media addiction, hijab, perceived social support, psychological resilience, religiosity, and social media unconsciousness. 260 women over 18 were included in this online study based on voluntariness and accessibility. Compatible with our hypotheses, a significant positive correlation was observed between body satisfaction and social support (r=0.29, p<0.01), psychological resilience (r=0.37, p<0.01) and religiosity level (r=0.21, p<0.01); and a negative significant correlation was found between body satisfaction and social media unconsciousness (r=-0,38, p<0.01), social media addiction (r= -0.35, p<0.01) and perception of others (r= -0.34, p<0.01). Multiple linear regression analysis results revealed that the model was statistically significant (F(4,255)= 22,86; p<0,001, *Adjusted* R^2 = 0.25); and social media unconsciousness, psychological resilience, religiosity, and perceived social support explained 25% of the total variance of body satisfaction. Independent sample t test results yielded the body satisfaction (M=34.78, SS=6.82) and religiosity (M=5.32, SS=1.01) of women with hijab were significantly higher than those who did not wear hijab (respectively M=32.93, SS= 6.89; M=4.06, SS=1.37), (respectively, t(258)= 2.1, p < 0.05; t(258)= 8.5, p < 0.001). Based on the demographic form question, named as "others perception" shortly, ("My physical features that I believe to be flawed, do not cause me any trouble as long as others do not see them"), the participants with hijab and without hijab were not differentiated. Our hypothesis that the clothing styles of women with hijab would protect them against body dissatisfaction was not supported. The findings indicated that social media unconsciousness negatively affected body satisfaction. Moreover, social support, psychological resilience, and religiosity would be considered protective factors. It was considered that psychoeducation aimed at increasing social media consciousness and psychotherapeutic interventions that support psychological resilience may be effective in reducing body dissatisfaction and providing protection from eating disorders associated with it.

Keywords: Social media, body satisfaction, perceived social support, psychological resilience, hijab

BEDEN MEMNUNİYETİYLE SOSYAL MEDYA BİLİNÇSİZLİĞİ İLİŞKİSİNİN TESETTÜR VE OLASI KORUYUCU FAKTÖRLER BAĞLAMINDA İNCELENMESİ

ÖZET

Bu çalışmada beden memnuniyetinin sosyal medya bağımlılığı, tesettür, algılanan sosyal destek, psikolojik sağlamlık, dindarlık ve sosyal medya bilinçsizliği ile ilişkisi çalışılmıştır. Çalışmaya 18 yaş üstü 260 kadın gönüllülük ve ulaşılabilirlik esasına göre dahil edilmiştir. Çalışma online olarak yürütülmüştür. Hipotezlerimize paralel olarak, beden memnuniyetinin sosyal destek (r=0,29, p<0,01), psikolojik sağlamlık (r=0,37, p<0,01) ve dindarlık seviyesi (r=0,21, p<0,01) ile arasında anlamlı ve pozitif korelasyon gözlemlenmiştir; sosyal medya bilinçsizliği (r=-0,38, p<0,01), sosyal medya bağımlılığı (r=-0,35, p<0,01) ve diğerlerinin algısı (r= -0,34, p<0,01) ile arasında ise negatif anlamlı bir korelasyon bulunmuştur. Regresyon analizi sonuçları incelendiğinde, modelin istatistiksel olarak anlamlı olduğu (F(4,255)= 22,86; p<0,00, düzeltilmiş R^2 = 0.39), sosyal medya bilinçsizliği, psikolojik sağlamlık, dindarlık seviyesi ve algılanan sosyal desteğin, beden memnuniyeti düzeyinin toplam varyansının %25'ini açıkladığı görülmüştür. Bağımsız örneklem t testi sonucuna göre ise tesettürlü kadınların beden memnuniyeti ($\bar{x}$=34,78, SS=6,82) ve dindarlık seviyesi ($\bar{x}$=5,32, SS=1,01), tesettürlü olmayanlardan (sırası ile $\bar{x}$=32,93, SS= 6,89; $\bar{x}$=4,06, SS=1,37) anlamlı şekilde yüksek bulunmuştur (sırası ile t(258)= 2,1, p < 0,05; t(258)= 8,5, p < 0,001). Demografik formda yöneltilen ve kısaca diğerlerinin algısı olarak isimlendirilen, "*Kusurlu olduğuna inandığım fiziksel özelliklerim başkaları tarafından görülmediği müddetçe benim için sıkıntı yaratmaz"* sorusuna verilen cevaplarda tesettürlü ve tesettürsüz katılımcı grubu faklılaşmamış ve tesettürlü kadınların giyim tarzlarının onları beden memnuniyetsizliğine karşı koruduğuna ilişkin hipotezimiz desteklenmemiştir. Söz konusu bulgular; sosyal medya bilinçsizliğinin beden memnuniyetini olumsuz etkilediğini, sosyal destek, psikolojik sağlamlık ve ek bir faktör olarak dindarlığın da koruyucu faktörler olarak dikkate alınabileceğine işaret etmektedir. Sosyal medya bilincinin artırılmasına yönelik psikoeğitimlerin ve psikolojik sağlamlığı destekleyen psikoterapötik müdahalelerin, beden memnuniyetsizliğinin azaltılmasında ve beden memnuniyetsizliği ile ilişkili yeme bozukluklarına ilişkin koruma sağlamada etkili olabileceği düşünülmüştür.

Anahtar Sözcükler: Sosyal medya, beden memnuniyeti, psikolojik sağlamlık, algılanan sosyal destek, tesettür

EXTENDED ABSTRACT

Introduction and Objectives: Nowadays, the use of social media has a significant impact on the body perceptions of individuals. Both social media addiction and social media unconsciousness (an excessive meaning a person attributes to how his/her images uploaded to social media appear to others) would lead people to feel dissatisfied with their bodies and make unfavorable social comparisons. It is thought that protective factors such as perceived social support and psychological resilience can reduce these adverse effects. Furthermore, some studies showed that hijab would also be a protective factor against body dissatisfaction, and women with hijab had higher body satisfaction compared to those who did not wear hijab. The present study explored the relationships between body satisfaction and social media addiction, hijab, perceived social support, psychological resilience, religiosity, and social media unconsciousness. The hypotheses of this study were: H1: There is a positive relationship between body satisfaction and psychological resilience, perceived social support, and religiosity. H2: There is a negative relationship between body satisfaction and social media unconsciousness and social media addiction. H3: Psychological resilience, perceived social support, social media unconsciousness, social media addiction, and religiosity predict body satisfaction. H4: There is a negative relationship between body satisfaction and participants' belief that their perceived physical flaws are related to other people's interest in their bodies (others' perception). H5: Body satisfaction of women with hijab is higher than that of other women, as their physical features, which they believe to be flawed, are not recognized by others (others' perception).

Method: Based on volunteering and accessibility, 260 women over 18 were included in this study, which was conducted online. The demographic information form, Body Appreciation Scale, Multidimensional Scale of Perceived Social Support, Brief Resilience Scale, The Appearance-related Social Media Consciousness Scale, and Bergen Social Media Addiction Scale were presented to the participants, respectively.

Findings: Compatible with our hypothese, a significant positive correlation was observed between body satisfaction and social support (r=0.29, p<0.01), psychological resilience (r=0.37, p<0.01) and religiosity (r=0.21, p<0.01); and a negative significant correlation was found between body satisfaction and social media unconsciousness (r=-0,38, p<0.01), social media addiction (r= -0.35, p<0.01) and "perception of others" (r= -0.34, p<0.01). Multiple linear regression analysis results revealed that the model was statistically significant (F(4,255)= 22,86; p<0,001), and social media unconsciousness, psychological resilience, religiosity level, and perceived social support explained 25% of the total variance of body satisfaction. Independent sample t test results yielded the body satisfaction (M=34.78, SS=6.82) and religiosity level (M=5.32, SS=1.01) of women with hijab were significantly higher than those of who did not wear hijab (respectively M=32.93, SS= 6.89; M=4.06, SS=1.37), (respectively, t(258)= 2.1, p < 0.05; t(258)= 8.5, p < 0.001). Based on the demographic form question, named as "others perception shortly, ("My physical features that I believe to be flawed, do not cause me any trouble as long as others do not see them"), the participants with hijab and without hijab were not differentiated, and our hypothesis that the clothing styles of women with hijab would protect them against body dissatisfaction, was not supported. Moreover, the participant groups with hijab and without hijab did not differ based on social media addiction, social media unconsciousness, psychological resilience, and perceived social support.

Discussion and Conclusion: The findings indicated that social media unconsciousness adversely affected body satisfaction. Furthermore, social support, psychological resilience, and religiosity would be considered protective factors. Even if our hypothesis that claimed women's

body satisfaction, who were wearing hijab, would be higher than others due to their clothing style, was not supported, it is still interesting that women with higher religiosity have higher body satisfaction as well. It was thought that this would be due to the characteristic nature of religion emphasizing spiritual values, such as altruism and morality, rather than material aspects, such as status and physical appearance. It was considered that psychoeducation aimed at increasing social media consciousness and psychotherapeutic interventions that support psychological resilience may be effective in reducing body dissatisfaction and providing protection from eating disorders associated with it.

Keywords: Social media, body satisfaction, perceived social support, psychological resilience, hijab

TAM ÖZET

Giriş ve Amaç: Günümüzde sosyal medya kullanımı, bireylerin beden algıları üzerinde önemli ve olumsuz etkiler yaratmaktadır. Gerek sosyal medya bağımlılığı gerekse sosyal medya bilinçsizliği (kişinin sosyal medyaya yüklenen görüntülerinin nasıl göründüğüne yüklediği aşırı anlam), bireylerin bedenlerinden memnuniyetsizlik duymalarına ve olumsuz sosyal karşılaştırmalar yapmalarına yol açabilmektedir. Algılanan sosyal destek ve psikolojik sağlamlık gibi koruyucu faktörlerin ise bu olumsuz etkileri azaltabileceği düşünülmektedir. Buna ek olarak yapılan bazı araştırmalar tesettürün de beden algısına karşı koruyucu bir etmen olabileceğini ve tesettürlü kadınların beden memnuniyetlerinin daha yüksek olduğunu göstermektedir. Bu çalışmada, beden memnuniyetinin sosyal medya bağımlılığı, tesettür, algılanan sosyal destek, psikolojik sağlamlık, dindarlık ve sosyal medya bilinçsizliği ile ilişkisi çalışılmıştır. Araştırmamızın hipotezleri; H1: Beden memnuniyeti ile psikolojik sağlamlık, algılanan sosyal destek ve dindarlık arasında pozitif bir ilişki vardır. H2: Beden memnuniyeti ile sosyal medya bilinçsizliği ve sosyal medya bağımlılığı arasında negatif bir ilişki vardır.H3: Psikolojik sağlamlık, algılanan sosyal destek, sosyal medya bilinçsizliği, sosyal medya bağımlılığı ve dindarlık, beden memnuniyetini yordar. H4: Beden memnuniyeti ile katılımcıların, bedensel olarak algıladıkları kusurlarının diğer insanların vücutlarına olan ilgileriyle ilişkili olmasına dair inançları (diğerlerinin algısı) arasında negatif ilişki vardır. H5: Tesettürlü kadınların beden memnuniyeti; kıyafet tarzları nedeniyle kusurlu olduklarına inandıkları fiziksel özelliklerinin başkaları tarafından görülmemesinden (diğerlerinin algısı) dolayı daha yüksektir.

Yöntem: Çalışmaya 18 yaş ve üzeri 260 kadın gönüllülük ve ulaşılabilirlik esasına göre dahil edilmiştir. Çalışma online olarak yürütülmüştür. Katılımcılara sırasıyla demografik bilgi formu, Beden Memnuniyeti Ölçeği, Çok Boyutlu Algılanan Sosyal Destek Ölçeği, Kısa Psikolojik Sağlamlık Ölçeği, Görünümle İlişkili Sosyal Medya Bilinç Ölçeği, Bergen Sosyal Medya Bağımlılığı Ölçeği sunulmuştur.

Bulgular: Hipotezlerimize paralel olarak, beden memnuniyetinin sosyal destek (r=0,29, p<0,01), psikolojik sağlamlık (r=0,37, p<0,01) ve dindarlık seviyesi (r=0,21, p<0,01) ile arasında anlamlı ve pozitif korelasyon gözlemlenmiştir; sosyal medya bilinçsizliği (r=-0,38, p<0,01), sosyal medya bağımlılığı (r=-0,35, p<0,01) ve diğerlerinin algısı (r= -0,34, p<0,01) ile arasında ise negatif anlamlı bir korelasyon bulunmuştur. Regresyon analizi sonuçları incelendiğinde, modelin istatistiksel olarak anlamlı olduğu (F(4,255)= 22,86; p<0,001), sosyal medya bilinçsizliği, psikolojik sağlamlık, dindarlık seviyesi ve algılanan sosyal desteğin, beden memnuniyeti düzeyinin toplam varyansının %25'ini açıkladığı görülmüştür. Bağımsız örneklem t testi sonucuna göre ise tesettürlü kadınların beden memnuniyeti ($\bar{x}$=34,78, SS=6,82) ve dindarlık seviyesi ($\bar{x}$=5,32, SS=1,01), tesettürlü olmayanlardan (sırası ile $\bar{x}$=32,93, SS= 6,89; $\bar{x}$=4,06, SS=1,37) anlamlı şekilde yüksek bulunmuştur (sırası ile t(258)= 2,1, p < 0,05; t(258)= 8,5, p < 0,001). Demografik formda yöneltilen "*Kusurlu olduğuna inandığım fiziksel özelliklerim başkaları tarafından görülmediği müddetçe benim için sıkıntı yaratmaz"* sorusuna verilen cevaplarda tesettürlü ve tesettürsüz katılımcı grubu farklılaşmamış ve tesettürlü kadınların giyim tarzlarının onları beden memnuniyetsizliğine karşı koruduğuna ilişkin hipotezimiz desteklenmemiştir. Tesettürlü grup ile tesettürsüz grup, sosyal medya bağımlılığı, sosyal medya bilinçsizliği, psikolojik sağlamlık ve algılanan sosyal destek açısından da farklılaşmamıştır.

Tartışma ve Sonuç: Söz konusu bulgular; sosyal medya bilinçsizliğinin beden memnuniyetini olumsuz etkilediğini, sosyal destek, psikolojik sağlamlık ve ek bir faktör olarak dindarlığın da koruyucu faktörler olarak dikkate alınabileceğine işaret etmektedir. Hipotezimiz doğrultusunda

tesettürlü kadınların giyim tarzları dolayısıyla bedenlerinin başkaları tarafından görülmemesinin beden memnuniyetlerini artıracağı fikri desteklenememiş olsa bile dindarlık düzeyi yüksek olan kadınların beden memnuniyetlerinin diğerlerine kıyasla yüksek olması ilgi çekicidir. Söz konusu durumun dinlerin görsellik, statü v.b. materyalist değerlerdense yardımseverlik, ahlak vb. manevi değerleri ön plana çıkarmasından kaynaklanabileceği düşünülmüştür. Sosyal medya bilincinin artırılmasına yönelik psikoeğitimlerin ve psikolojik sağlamlığı destekleyen psikoterapötik müdahalelerin, beden memnuniyetsizliğinin azaltılmasında ve beden memnuniyetsizliği ile ilişkili yeme bozukluklarına ilişkin koruma sağlamada etkili olabileceği düşünülmüştür.

Anahtar sözcükler: Sosyal medya, beden memnuniyeti, psikolojik sağlamlık, algılanan sosyal destek, tesettür

INVESTIGATION OF THERMAL EFFICIENCY IN LIQUID-COOLED LITHIUM-ION BATTERY SYSTEMS

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ABSTRACT

This study investigates the thermal performance of cooling strategies for lithium-ion battery systems using three-dimensional, time-based (transient) simulations with FloEFD software. The main goal is to clearly understand how the type of coolant, the speed of the fluid (Reynolds number), and the discharge rate affect battery cell temperature. A special part of this work is that it tests antifreeze mixtures like EG, normally used in freezing weather, under mild, non-freezing conditions. This helps check if fluids designed for cold temperatures also work well in normal situations. Three coolant mixtures—100% water, 70% water - 30% ethylene glycol (EG), and 50% water - 50% EG—were tested. Each was analysed with Reynolds numbers of 500, 1000, and 2000, and discharge rates of 1C, 2C, and 4C. The results show that battery temperatures are affected by discharge rate, fluid speed, and coolant type. When the discharge rate increases, battery temperature goes up quickly. Higher Reynolds numbers help improve cooling by increasing heat transfer, but this effect is smaller than the effect of discharge rate. Coolant performance changed depending on the fluid speed. At low flow speeds (Re = 500–1000), the 50% water–50 % EG mixture gave the best results because of its good viscosity. Water was best at high flow speed (Re = 2000) because it transfers heat better. The 70% water–30 % EG mixture gave steady but average performance in all tests. In conclusion, the study shows that for good thermal control, both the coolant type and flow speed must be considered together.

Keywords: Thermal performance, Discharge, Liquid Cooling, Ethylene Glycol (EG), Water

COMPARISON OF INTERNET OF THINGS (IOT) USE CASES AND COMMUNICATION TECHNOLOGIES

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ABSTRACT

The Internet of Things (IoT) is a technology that enables physical objects to communicate and share data over the internet. Today, this technology is widely used in many areas such as industrial automation, healthcare systems, smart city applications, agriculture, and transportation. One of the most important elements of IoT systems is the selection of a communication technology that meets the specific requirements of the application. This paper presents a comparative analysis of communication protocols commonly used in IoT applications, including LoRaWAN, NB-IoT, Zigbee, Wi-Fi, and Bluetooth. The technical characteristics of each technology are examined and the advantages and disadvantages of these technologies are evaluated in terms of parameters such as coverage, data rate, latency, scalability, and energy efficiency. It also discusses the suitability of each protocol in different use cases. For example, LoRaWAN is preferred in rural applications requiring long range and low power consumption, while Wi-Fi is preferred in applications requiring high data rate and short range. In this context, it is of great importance to make the right choice in system design by considering both the technical and application level performance of the protocols. The results of this study will provide guidance for both academic research and industrial applications. This study aims to guide researchers, engineers and decision makers in choosing the most appropriate communication protocol for their IoT applications. As a result, it will contribute to a more efficient design of IoT systems by matching communication technologies with application goals.

Keywords: Internet of Things (IoT), IoT communication protocols, LoRaWAN, NB-IOT.

NESNELERİN İNTERNETİ (IOT) KULLANIM ALANLARI VE HABERLEŞME TEKNOLOJİLERİNİN KARŞILAŞTIRILMASI

ÖZET

Nesnelerin interneti (IoT), fiziksel nesnelerin internet aracılığıyla birbirleriyle haberleşmesini ve veri paylaşımını sağlayan bir teknolojidir. Günümüzde bu teknoloji; endüstriyel otomasyon, sağlık sistemleri, akıllı şehir uygulamaları, tarım ve ulaşım gibi pek çok alanda yaygın olarak kullanılmaktadır. IoT sistemlerinin en önemli unsurlardan biri, uygulama gereksinimlerine uygun haberleşme teknolojisinin seçilmesidir. Bu çalışma, IoT uygulamalarında yaygın olarak kullanılan LoRaWAN, NB-IoT, Zigbee, Wi-Fi ve Bluetooth gibi haberleşme protokollerinin karşılaştırmalı bir analizini sunmaktadır. Her bir teknolojinin teknik özellikleri incelenmiş; kapsama alanı, veri iletim hızı, gecikme süresi, ölçeklenebilirlik ve enerji verimliliği gibi parametreler açısından bu teknolojilerin avantajları ve dezavantajları değerlendirilecektir. Ayrıca, her bir protokolün farklı kullanım senaryolarındaki uygunluğu tartışılacaktır. Örneğin, LoRaWAN'ın uzun menzil ve düşük güç tüketimi gerektiren kırsal alan uygulamalarında tercih edilmesi, ya da Wi-Fi'ın yüksek veri hızı ve kısa menzil gerektiren uygulamalardaki avantajı gibi örnekler ele alınmıştır. Bu bağlamda, protokollerin hem teknik hem de uygulama düzeyindeki performansları göz önünde bulundurularak sistem tasarımında doğru tercihin yapılması büyük önem taşımaktadır. Çalışmada elde edilen bulgular, hem akademik araştırmalar hem de endüstriyel uygulamalar için yol gösterici nitelikte olacaktır. Bu çalışma, araştırmacılar, mühendisler ve karar vericilere kendi IoT uygulamaları için en uygun haberleşme protokolünü seçmede rehberlik etmeyi amaçlamaktadır. Sonuç olarak, haberleşme teknolojilerinin uygulama hedefleriyle uyumlu hale getirilmesi yoluyla IoT sistemlerinin daha verimli şekilde tasarlanmasına katkı sağlayacaktır.

Anahtar Kelimeler: Nesnelerin interneti (IoT), IOT haberleşme protokolleri, LoRaWAN, NB-IOT.

DESIGN OF A WEARABLE ANTENNA INTEGRATED ONTO MILITARY BERETS OR KASKS FOR INDOOR/OUTDOOR POSITIONING SYSTEMS

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ABSTRACT

To meet the communication and positioning needs of civil or military personnel in the field, an innovative wearable antenna design has been developed, which can be integrated into military berets. This design operates simultaneously in both the RFID (915 MHz) and GPS L1 (1.575 GHz) frequency bands. The system provides operational flexibility by enabling secure identification in indoor environments and precise positioning in outdoor scenarios. By utilizing textile-based materials in the antenna structure, a significantly lighter and more flexible form has been achieved compared to conventional solutions. This approach enhances the portability of the antenna while minimizing the physical burden on the user. The design includes a hexagonal slot RFID patch optimized for identification in indoor environments, and a slotted rectangular GPS patch intended for real-time positioning in outdoor operations. This configuration prioritizes mobility and ease of integration, aiming to provide an effective communication infrastructure in the field. Electromagnetic simulation results confirm that the system exhibits proper impedance matching, low return loss, and desired radiation patterns in both frequency bands. The RFID antenna demonstrates an omnidirectional radiation characteristic, whereas the GPS antenna exhibits an upward directional pattern. Especially, return-loss values below -10 dB and well-obtained radiation characteristics indicate that the system delivers reliable performance in dual-band communication scenarios. Thanks to its ergonomic structure, the antenna is suitable for long-term use without limiting the mobility of military personnel, providing a practical and efficient solution for field communication needs.

Keywords: Wearable microstrip antenna, Dual-band antenna design, RFID and GPS systems

A COMPARATIVE ANALYSIS OF ANTONYMS IN MEDICAL, TECHNICAL AND LINGUISTIC TERMINOLOGY IN PERSIAN, ENGLISH AND AZERBAIJANI LANGUAGES

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ABSTRACT

Antonymy is an important semantic phenomenon widely used both in everyday speech and in specialized terminology. This study presents a comparative analysis of antonymic pairs in medical, technical, and linguistic terminology across three languages: Persian, English, and Azerbaijani.

Antonyms can be classified into several types: contrary antonyms express opposite extremes of the same quality (e.g., big – small), complementary antonyms are mutually exclusive, with no intermediate state (e.g., alive – dead), relational antonyms are based on reciprocal relationships (e.g., teacher – student), directional antonyms indicate opposite directions or movements (e.g., enter – exit), gradable antonyms show varying degrees of a quality (e.g., warm – cold), and conversive antonyms describe the same situation from different perspectives (e.g., buy – sell).

In medical terminology, complementary antonyms are most common, such as هیپرتانسیون / هیپوتانسیون (hypertension / hypotension), bradycardia / tachycardia, and bradikardiya / taxikardiya.

In technical vocabulary, relational and directional antonyms predominate, for example: input / output, خروجی / ورودی, giriş / çıxış.

Linguistic terminology includes all major types of antonyms: active / passive, məlum / məchul, معلوم / مجهول.

The comparative approach reveals typological similarities and differences in how opposition is expressed across languages. The analysis shows that while the underlying concepts are largely universal, the linguistic means of expressing them vary significantly, particularly at the morphological and syntactic levels. This research is relevant for terminological lexicography, machine translation, and cross-linguistic semantics.

Keywords: Persian language , English language ,Azerbaijani language ,terminology, antonyms

THE CASE OF TWO SIMILAR HAIKU POEMS

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ABSTRACT

The purpose of this paper is to present the phenomenon of two very similar poems found in a weekly haiku contest in the Haiku Authors from Romania Facebook group. The similarity was unwilling, as the two authors did not talk together and did not share previously these poems in print or online. Fresh poems only are received in this contest. One of the poems sounds as follows: "marți treisprezece –/ fărâmițe pe tejghea/ trei ceasuri rele" (Tuesday the thirteenth –/ scattered into pieces on the counter/ three evil hours, my translation). The poem belongs to Andrei Andy Grădinaru. In my translation, I used evil hours for what is called, in Romania, when we have bad luck on a Tuesday. At the same time, hours and clocks or watches are designated by the same word in Romanian. There could be real clocks or watches shattered on the counter. We could also use cursed clocks or watches. The ambiguity cannot be captured in translation. The ideas and suggestions related to bad luck come together coherently: not only is it Tuesday, but it is also the 13th, and even the bad or evil hours, a symbol of misfortune, are shattered on the counter. The clocks could be old objects, cherished at flea markets, but they can no longer be valued. Alternatively, we could interpret it as bad luck having been banished after all. The second poem, by Valer C. Pop, sounds as follows: "zi de marți –/ pe o tarabă în talcioc/ 3 ceasuri rele" (Tuesday –/ on a flea market table/ three cursed clocks, my translation). The resemblance is clearly striking. For the theoretical methodology, the paper relies on literary studies and psychoanalysis, on reader response criticism and on the theory of synchronicity by Jung.

Keywords: free associations, allusions, synchronicity.

DETERMINATION OF THE STRUCTURE AND EVALUATION OF DECORATIVE TREES IN "NËNË TEREZA" SQUARE, PRISHTINA

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ABSTRACT

Decorative trees in urban spaces represent more than just aesthetic elements; they are essential forimproving quality of life and creating sustainable cities. With a direct impact on air quality improvement, thermal balancing, and rainwater management, these trees constitute a valuable economic and ecological asset for urban communities. This study aims to evaluate the decorative trees in “Mother Teresa” Square in Prishtina, prioritizing their monetary and non-monetary values. The focus is on identifying species, assessing their health, and analyzing their impact on urban living quality. The methodology includes key factors such as: Base Price (A): Determination of the initial value of the tree in the nursery. Age Factor (B): Assessment of age to measure the impact of growth and development. Location and Protection (C): Analysis of the tree's strategic positioning in urban space. Crown Condition (D): Visual assessment of crown coverage and density. General Condition (E): Health evaluation of key tree parts, including roots, trunk, and leaves. Dendrological Value (M): Analysis of the biological and aesthetic importance of the tree species. An advanced approach based on the Hungarian model adopted by the European Commission is utilized. The results demonstrate that the evaluated decorative trees have a multifaceted impact on enhancing urban quality of life and sustainable city planning. Integrating these values into urban strategies is recommended to protect and maintain green spaces. This study highlights the necessity of treating decorative trees as essential elements of urban planning. Comprehensive assessment models, such as the Hungarian model, provide the foundation for effective policymaking that enriches life in 21st-century cities. In total, 28 species of decorative trees are present in “Mother Teresa” Square, with 195 decorative trees recorded, amounting to a total value of 821,188.2€.

Keywords: Decorative trees, evaluation, sustainability, urban environment.

GRENADINE MOLASSES: BETWEEN PROMISES AND CHALLENGES

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ABSTRACT

Pomegranate syrup, or pomegranate molasses, is a traditional product rich in bioactive compounds such as polyphenols (punicalagin, ellagic acid), flavonoids, and anthocyanins, recognized for their antioxidant, anti-inflammatory, and cardiovascular protective effects. While scientific research has confirmed, through clinical trials, the benefits of pomegranate juice or extracts on memory, heart health, metabolism, and immunity, few studies have yet specifically targeted artisanal molasses. However, the prolonged cooking used in its production can alter certain sensitive molecules, while preserving or activating other, more stable compounds. Promoting local pomegranate varieties, adapted to Mediterranean terroirs and rich in tannins, offers promising potential for combining ancestral knowledge, sustainable production, and innovation in preventive health, from an epistemological perspective linking tradition and science.

Keywords: *Punica granatum* L., grenadine molasses, natraceutical, local cultivar, tannins, arid region,

DIGITAL TRANSFORMATION AND INNOVATION: THE ROLE OF TECHNOLOGY IN SHAPING SOCIO-ECONOMIC DEVELOPMENT

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ABSTRACT

The 21st century has been marked by rapid advancements in digital technologies, profoundly transforming economic systems, social structures, and human interactions. This study explores the dynamics of digital transformation with a focus on its socio-economic implications, particularly in developing countries. The research investigates how technological innovations such as artificial intelligence, big data, and automation are redefining labor markets, access to services, and public governance. Using a mixed-method approach combining secondary data analysis and case studies from the Balkan region, the study identifies key opportunities and challenges brought by digitalization. The findings reveal a growing digital divide, but also highlight the potential for inclusive growth through strategic investment in digital literacy and infrastructure. The paper concludes with policy recommendations aimed at fostering an innovation-driven ecosystem that ensures sustainable development and social equity. This study contributes to the interdisciplinary discourse on current developments in science, technology, and social sciences, aligning with the objectives of the 11th BILTEK Congress.

Keywords: digital transformation, innovation, socio-economic development, technology, public policy, digital divide

WOMEN AND FOOD TOURISM: EXPLORING GENDER ROLES IN CULINARY TRADITIONS OF SOUTHEASTERN NIGERIA

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ABSTRACT

Food tourism has emerged as a vital avenue for preserving cultural heritage and fostering local economic development, particularly in indigenous communities. In Southeastern Nigeria, where culinary traditions are deeply rooted in the socio-cultural fabric of the Igbo people, women play a pivotal role as custodians, creators, and transmitters of food-related knowledge and practices. This study explores the gendered dimensions of food tourism by examining the roles, contributions, and challenges of women in sustaining and promoting culinary traditions in selected communities in Anambra, Enugu, and Abia States. Using a qualitative methodology that includes ethnographic fieldwork, interviews, and participant observation, the research uncovers how women not only preserve traditional recipes and cooking techniques but also act as cultural ambassadors through food festivals, local markets, and tourism-oriented food enterprises. Findings reveal that women's participation in food tourism fosters community cohesion, intergenerational knowledge transfer, and economic empowerment, despite facing socio-cultural and structural barriers. The paper argues that integrating gender perspectives into food tourism development can enhance cultural sustainability and create inclusive economic opportunities in rural and peri-urban areas. The study concludes with recommendations for policy frameworks that support women-led culinary initiatives as a strategic component of sustainable tourism development in Southeastern Nigeria.

Keywords: Food tourism, gender roles, culinary traditions, women in tourism, Southeastern Nigeria

WOMEN IN RURAL SLOVENIA NAVIGATING THE TRIPLE BURDEN OF LABOUR, AGRICULTURE AND HOUSEHOLD CARE

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ABSTRACT

This research highlights the overlooked challenges faced by rural women in Slovenia who are in paid employment, run family farms and perform most household tasks. As Eurostat (2024) states, rural women often have less access to services, infrastructure and technology, and their contributions are underestimated or remain invisible.

Despite the high labour force participation of women in Slovenia, rural women take on a disproportionate amount of unpaid care work. They look after children and elderly relatives, contribute to agricultural work and often work outside the home. However, national labour and agricultural policies offer little recognition or support (Petrovčič et al., 2023; Stajnko, 2016; FAO, 2011).

These challenges are exacerbated by digital exclusion. Rural women have limited access to digital tools, internet services and digital education — especially those with lower incomes, less education or disabilities (UN Women, 2022; IFPRI, 2024). This inequality hinders their participation in modern agriculture, e-services and the digital economy. In 2021, only 17% of ICT professionals in Slovenia were women, indicating broader structural barriers (Selič & Kamenšek, 2023).

Deep-rooted gender norms also persist - women usually take on the care and administrative work in agriculture, while men dominate the decision-making functions. These constraints limit women's well-being and economic participation.

Rural women bear a triple labour burden yet remain underrepresented in policy and statistics. To advance gender equality and rural sustainability, we recommend strengthening rural care infrastructure (childcare, eldercare, social services), promoting shared care responsibilities within families, mainstreaming gender in rural and agricultural policies and investing in rural connectivity and digital training for women. Targeted support is essential to ensure rural women are not left behind in digital and societal transitions.

Keywords: Rural women, Unpaid care work, Digital exclusion, Gender inequality, Agricultural policy.

AN INTELLIGENT SYSTEM FOR THE EVALUATION OF SCIENTIFIC PAPERS BASED ON FUZZY LOGIC

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ABSTRACT

Objective and comprehensive evaluation of scientific papers remains one of the most critical and complex challenges in the academic and research community. The accuracy and fairness of the review process are essential for ensuring the integrity and credibility of scholarly publishing. However, the evaluation often heavily relies on the reviewer's subjective judgment, which is shaped by their individual experience, personal bias, expertise, and interpretation of academic standards. As a result, different reviewers may produce inconsistent or even contradictory evaluations of the same work. This subjectivity compromises the transparency and reliability of the final decision regarding acceptance, revision, or rejection of submitted papers.

Traditionally, academic papers are evaluated based on multiple qualitative criteria such as the relevance of the research topic, originality and innovation, soundness of the methodology, significance and potential impact of the results, clarity of the presentation, and adherence to

ethical standards. While these criteria are valid and widely accepted, their interpretation varies among reviewers.

To address these challenges and reduce the influence of subjective bias, this paper proposes an intelligent evaluation system based on fuzzy logic. Fuzzy logic allows for handling uncertainty and ambiguity in human reasoning by using linguistic variables and rule-based decision-making. The proposed system incorporates a multi-criteria assessment framework, combining expert-defined rules with fuzzy inference mechanisms to derive a consistent and balanced evaluation.

This model has been implemented as software and integrated into the peer review workflow. It assists editors and reviewers by offering a structured and systematic evaluation process, improving decision-making accuracy, enhancing fairness, and increasing trust in the peer review process.

Keywords: Fuzzy Logic, Intelligent System, Scientific Papers, Evaluation.

ETHNOMUSICOLOGICAL PERSPECTIVE OF EBENEZER OBEY'S SONG "OPERATION FEED THE NATION" ON FOOD SOVEREIGNTY IN SOUTH WEST NIGERIA

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ABSTRACT

This study examines Ebenezer Obey's song "Operation Feed the Nation" from an Ethnomusicological perspective, analyzing its impact on food sovereignty in South West Nigeria. The research reveals how the song promoted self-sufficiency, agricultural development, and community empowerment, reflecting Yoruba cultural values. This research is relevant to Sustainable Development Goals number 2 (Zero Hunger), and number 3 (Good Health and Wellbeing). The objectives of this study are to analyze the lyrical content of "Operation Feed the Nation" in relation to food sovereignty; examine the impact of the song on agricultural development in South West Nigeria and to investigate how the song promoted community empowerment and self-sufficiency. This study made use of the content analysis of song lyrics, historical context analysis of Nigeria's food sovereignty initiatives, and literature of relevant Ethnomusicological and agricultural development studies. The findings of this study show that the song's lyrics emphasized self-sufficiency and agricultural development and the song contributed to increased awareness and mobilization for food production. This study therefore recommends the integration of music into agricultural development initiatives; promotion of traditional Yoruba Music and cultural values, and the need to carry out further research on the impact of music on food security.

Keywords: Food Sovereignty, Indigenous Songs, Ethnomusicology, Agriculture.

THE MECHANISM BETWEEN THE OPTIMIZATION OF RURAL EDUCATIONAL RESOURCES AND REGIONAL AGRICULTURAL ECONOMIC

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ABSTRACT

Revitalization This study aims to investigate the interactive dynamics between the optimization of educational resources in rural areas and the revitalization of regional agricultural economies. Utilizing panel data from 31 provinces across China spanning the years 2018 to 2023, this research will employ spatial econometric techniques to empirically assess the relationship concerning the dynamics and regional disparities within the education-agriculture interplay.

The detected positive correlations range from 0.342 to 0.412 in the different model settings for interaction terms while optimizing educational resources in support of agricultural economic development. It could be seen from the regional heterogeneity analysis that the strength of the interaction effects in the Eastern region was higher, with a mean coefficient of 0.85, as compared to the Central and Western regions, which were 0.65 and 0.45, respectively. Resource misallocation and institutional constraint were the main operational problems suggested by the survey. Based on the above foundation, the study gives some policy suggestions that would increase effectiveness in the allocation of educational resources and promote coordinated rural development. This adds to the theoretical understanding of rural development by setting up a framework through which the interaction of education and agri-culture can be analyzed, providing ample insight into approaches toward policy formulation and implementation.

Among all the global development strategies, the optimization of rural educational resources and the re-vitalization of the regional agricultural economy have been two of the most critical thoughts thus far[1]. Inthe last few decades, scholars and policy makers havedeveloped an interest in the complex inter-relationships between means of distribution of educational resourcesand agricultural economic development[2]. New tech-nologies and rapid changes in how agriculture is being done need the rural workforce to be complicated and ed-ucated[3]. This in return would point out the need toimprove the educational resources within the rural set-ting, especially within agricultural and developing partsof the world. The interaction mechanisms should be uti-lized in solving the inharmoniousness between rural ed-ucation and agricultural growth because it is acting as ahindrance towards building up China's socialist new ru-ral area's, and it is indeed a pressing issue around the country's development[4].The literature available suggests that better utilization of educational inputs has a strong bearing on agri-cultural output and, consequently, economic develop-ment in rural areas[5]. Historically, rural areas have wit-nessed many setbacks regarding the distribution of educational resources due to inadequate infrastructure, in-sufficient quality education, and inequality in teacher distribution[6]. Using China as a case study, it is evi-dent from the statistics that a meager 91.4% gross enrollment rate was recorded for junior secondary education. According to statistics from 2022, fewer than 55.2% of teachers serving in rural areas possess a bachelor's de-gree or higher, whereas in cities the rates are 99.6% and91.3%[7] respectively. Further, there exists a challengeto agricultural modernization involving the digital trans-formation of rural areas. In 2022, it was reported thatonly 57.6% of people in rural China had access to theinternet,

which falls short by 26.8 percentage points ofurban penetration rates[8]. The recent imperatives withrespect to agricultural modernization and digitalization have added to the already complex load that besets the rural education framework, calling for a revisit of thetraditional resource allocation practice[9]. That problem further increases because of complexity in the develop-ment and modernization of agriculture in space[10].

The complex interaction of rural education re-sources and agricultural economic development formsa system that needs deep analysis on many levels [11].

Without understanding how such interrelation works, itwill not be possible to create policies enhancing educational quality that will increase parallel development in agricultural economics[12]. Recent research has pointed to the need for a fuller understanding of how educational resources come to be used, including how they can be best deployed to underpin sustainable agricultural delopement and rural renewal[13]. Indeed, many of the existing research limit themselves to the unidirectional correlational study only and they do not possess a theo-retical perspective that incorporates both into an inter-active system[14].

Keywords: Improvement of Learning Outcomes; Rejuvenation of Farm Economies; Interactive Models; RegionalGrowth; Space Econometrics

WHOLE GENOME SEQUENCING OF NONTYPHOIDAL *Salmonella* ISOLATED FROM FOOD-ANIMAL PRODUCTS IN BEJAIA, ALGERIA

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ABSTRACT

Nontyphoidal *Salmonella* presents a significant threat to animal and human health as a food-borne infectious agent. This study focused on the characterization of *Salmonella* isolates obtained from fresh animal products consumed in Bejaia, Algeria. In total, 495 beef products, 600 chicken products, and 355 dairy products were collected from retail outlets and slaughterhouses in the region. Out of the 1450 samples collected, a *Salmonella* positivity rate of 3.5% (51/1450) was observed. Traditional Algerian sausages exhibited the highest prevalence of *Salmonella* contamination (14.1%, 36/256). Fifteen different serotypes were identified, with *S.* Kentucky (n = 12), S. Anatum (n = 11), and S. Bredeney (n = 9) being the most prevalent. Antimicrobial susceptibility testing showed resistance to diverse antibiotics, particularly against tetracycline, ampicillin, nalidixic acid, and sulphonamides. Whole-genome sequencing conducted on 21 isolates enabled the comparison of phylogenetic links between isolates. We notably identified clones circulating across the region in different locations and food types, suggesting contamination at the early stages of the food chain (in the herd or slaughterhouses) that disseminated to numerous butcher shops in various cities. We also identified acquired antibiotic resistance genes and point mutations in the quinolone resistance-determining region genes, contributing to the observed resistance patterns. This study describes the genomic and phylogenetic characteristics of several *Salmonella* clones found in diverse food samples in Algeria. It suggests potential transmission dynamics that could better understand *Salmonella's* contamination routes.

Keywords: *Salmonella*, serotype, food product, whole-genome sequencing, antimicrobial resistance

BIOACTIVE MOLECULES FROM *SCABIOSA STELLATA* AS POWERFUL INHIBITORS OF CYCLOOXYGENASES 1 AND 2, 5-LIPOXYGENASE, AND NF-KB PROTEIN: *IN VIVO*, MOLECULAR DOCKING, AND *IN SILICO* APPROACHES

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ABSTRACT

This study is devoted to the determination of the chemical composition and the assessment of *in vivo* anti-inflammatory activity of the species *Scabiosa stellata* L. Furthermore, four saponins were isolated from the n-butanol extract using several chromatographic methods, and their structures were identified by spectroscopic analysis. The isolated compounds were subjected to molecular docking study with COX-1 and 2, 5-LOX, and NF-κB enzymes to explain the observed *in vivo* anti-inflammatory activity, and their pharmacokinetic and toxic parameters were predicted. According to the results, all the isolated compounds interact well with the active sites of COX-1 and 2, 5-LOX, and showed excellent interaction scores. The saponins demonstrated low intestinal absorption and poor skin, blood-brain barrier, and central nervous system permeability. However, all the molecules had low clearance values and a high drug half-lifetime (t1/2). On the other hand, the compounds had a low possible toxicity and lacked hepatotoxicity, mutagenicity, or cytotoxicity. In addition, the administration of the extract at 75 mg/kg prevents acute paw edema significantly compared to diclofenac. Furthermore, the plant may treat inflammatory diseases. However, a prudent use is recommended due to its richness in saponins known for their toxic effects.

Keywords: *Scabiosa stellata*, phytochemicals, anti-inflammatory, molecular docking, *in silico.*

A SYSTEMATIC LITERATURE REVIEW ON THE PHYTOCHEMICAL AND INSECTICIDAL PROPERTIES OF PLANT OILS AND EXTRACTS AGAINST CERATITIS CAPITATE

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ABSTRACT

Farmers use biopesticides, naturally occurring compounds, to control agricultural pests in forests, gardens, and farmlands. Scientists have produced diverse biopesticides using a range of sources. This systematic review evaluates the efficacy of plant-based bioinsecticides in controlling Ceratitis capitata populations by analyzing 29 research papers and using computer programs such as Zotero, Excel, and NVivo. Researchers found that essential oils from plants like Thymus herba-barona, Cinnamomum zeylanicum, Salvia officinalis, and other Eucalyptus species are highly harmful to adult medflies, with key active components being phenolic chemicals and aromatic aldehydes. Essential oils from Thymus zygis, Salvia officinalis, and Mentha suaveolens can kill insects and keep them away, making them suitable for integrated pest management plans. Melaleuca alternifolia and Carlina acaulis are poisonous, reducing their impact on parasitoids. The study also examined the non-lethal effects of essential oils on medfly behavior, including reduced aggressiveness and preference for certain oil mixes. These findings suggest that the use of plant-based bioinsecticides could significantly influence sustainable and eco-friendly pest management approaches, reducing reliance on chemical insecticides and mitigating their adverse impacts on human health and the environment.

Keywords: Insecticidal Properties, Ceratitis capitata, Bioinsecticide, pest Management, Systematic Review.

COMPREHENSIVE PHYTOCHEMICAL PROFILING VIA HPLC-MS/MS AND BIOACTIVITY ASSESSMENT OF *Ebenus pinnata:* A PROMISING MEDICINAL PLANT RESOURCE

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ABSTRACT

This study presents the first comprehensive analysis of *Ebenus pinnata*, an endemic medicinal shrub with significant ethnopharmacological importance in Mediterranean coastal regions. Systematic evaluation reveals this species as an exceptional reservoir of bioactive compounds with remarkable therapeutic potential. Understanding their exact compositions, particularly in bioactive molecules, is crucial for enhancing the value of plant matrices and their derivatives. HPLC-MS/MS analysis offers advantages such as high sensitivity, excellent compound separation, and precise molecular identification, while enabling comprehensive metabolite profiling.

This study explores the application of HPLC-MS/MS in characterizing extracts from various parts of this medicinal plant. It also documents striking tissue-specific phytochemical variations, with leaves showing significant phenolic content (526.90 ± 11.61 mg GAE/g DW) and flavonoids (369.23 ± 7.14 mg QE/g DW), while flowers exhibited superior

proanthocyanidin content. These findings highlight the importance of organ-specific analyses when evaluating medicinal plants. The robust antihemolytic capacity demonstrated across multiple assays like hypotonic test with IC50 of 1.58 mg/ml, validates traditional applications and suggests utility in oxidative stress-related disorders. The selective cytotoxicity of leaf extracts against murine multiple myeloma cells (IC50 = 276.1 ± 8.12 µg/mL), with minimal toxicity toward normal splenic mononuclear cells, suggests intriguing anticancer properties with potentially favorable therapeutic indices. These results scientifically validate traditional medicine applications and establish a foundation for bioprospecting novel therapeutic agents from *E. pinnata*, positioning it as a valuable botanical resource with significant potential for pharmaceutical development and addressing pressing global health challenges.

Keywords: *Ebenus pinnata Aiton*., Antihemolytic, TPC, TFC, HPLC-MS/MS

FUNGAL CONTAMINATION UPON ACADEMIC LABORATORY, A BIOSAFETY VIEW

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ABSTRACT

Biosafety is an important concept, Fungal contamination in academic laboratories was not within concern despite of its effect on the academic microbiological researches as contaminant and the obtained results. This study targeted to scan the most common contaminant fungi distributed in different sites and location indoor and outdoor academic laboratories. Detection was accomplished using routine microbiological methods (phenotype and cultural characteristics) and microscopic examination. Results revealed that *Aspergillus* sp. was the most common dominant mold, while *Candida* sp. was the most dominant yeast isolated. Then come several pathogenic and non-pathogenic fungi, like *Mucor* sp., *Rizopus* sp., *Fonsecaea* sp., *Trichophyton* sp. And *Exophilia* sp.. Conclusion: Surfaces and sites of Medical academic laboratories, which are in usual contact with hands, mainly need more focus in decontamination and the methods used locally in routine decontamination require check and updating according to Biosafety measures.

Keywords: Biosafety, fungal contamination, *Aspergillus, Candida, Fonsecaea, Trichophyton* And *Exophilia.*

ASSESSING EFFECT OF AGROECOLOGY ON SOIL ORGANIC MATTER AND THE AGRO- PHYSIOLOGICAL CHARACTERISTICS OF APPLE TREE

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ABSTRACT

Climate change is putting increasing pressure on land and water resources reducing vegetative growth and soil fertility, with a direct impact on global food security. Among the measures for adapting these challenges, agroecology appears to be a promising approach, with its many advantages, including numerous advantages, including the generation of a favorable microclimate at plot level and the improving soil fertility. For this reason there is the need to validate a new agroecosystem adapted to our present environment. The present study aims to evaluate the effect of agroecology based on the apple tree on the agro-physiological parameters of three intercrops and on the organic matter of the soil. The experimental dispositive consists of apple varieties, including 2 early varieties (Anna and Dorsett Golden), 2 seasonal varieties (Golden delicious and Starking delicious) and 2 late varieties (Story and King Roat). The intercrops used are rosemary, rapeseed and Faba bean. In the conventional system (control), two varieties are used; Golden delicious and Starking delicious. The parameters measured in the apple tree are leaf temperature, total chlorophyll, leaf area and stomatal conductance. Thus, the soil organic matter content was measured after harvest and in comparison, to before seedling. Significant variability for all the parameters measured was observed between the control and the apple tree and in comparison, between the two species. For example, the agroecology system favors the reduction of stomatal conductance compared to the controls in the apple tree. Regarding the organic matter content, the results obtained show an increase in its content compared to the monoculture. Although the results are preliminary, the study shows beneficial effects of this cropping system on apple tree.

Keywords: *Agroecology, Apple tree, Climate change, Organic matter, Physiological parameters.*

ROLE OF GhFBN IN DROUGHT TOLERANCE IN COTTON

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ABSTRACT

Fibrillin (FBN) proteins play crucial roles in plastid structure, stress responses, and lipid-associated functions which mediate drought tolerance in plants. The fibrillin (FBN) gene family, critical for stress adaptation in plants, remains poorly characterized in cotton. This study hypothesizes Fibrillin (FBN) orthologs in cotton confer drought tolerance. In this study, protein sequence of the Arabidopsis thaliana FBN family member was retrieved from TAIR and used as reference in cotton genomes and 18 members were selected as GhFBN orthologs based on high level of FBN domain homology. Subsequent sub-cellular localization analysis predicted FBN to be localized in chloroplast, endoplasmic reticulum (ER) and mitochondria indicating that GhFBN proteins are distributed across multiple organelles and may have multiple functions. Motif analysis using the MEME revealed that FBN members have conserved amino acid patterns which were confirmed by sequence logos checked by WebLogo tool, highlighting conserved structural features across species. To further decipher the function, chromosomal localization of FBN genes showed that these GhFBN genes in cotton are unevenly distributed across chromosomes 01, 04, 05, 06, and 07, and are classified into six phylogenetic groups. The online RNA sequencing expression data of all the identified GhFBN members displayed higher expression levels of certain GhFBN members confirmed by qRT-PCR. Our study offers valuable data on the function of GhFBN genes under drought stress and provides a foundation for further analysis of the function of the FBN gene family under abiotic stresses.

Keywords: Cotton, drought stress, FBN, GhFBN, Fibrillin.

SYSTEMATIC LITERATURE REVIEW ON ADOPTION OF DIGITAL TECHNOLOGIES IN AGRICULTURAL ACCOUNTING AND AUDIT

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ABSTRACT

This Systematic Literature Review (SLR) critically examines the integration and evolution of digital technologies in the field of agricultural accounting and auditing, a domain that is becoming increasingly significant in light of the widespread digital transformation within the agricultural industry. Drawing on scholarly publications spanning from 2010 to 2024, this review identifies and analyzes the application of advanced technologies such as farm management information systems (FMIS), blockchain technology, the Internet of Things (IoT), artificial intelligence (AI), and cloud-based platforms.

The findings underscore how these innovations are reshaping financial reporting, compliance, and decision-making processes in agriculture by enhancing data transparency, financial accuracy, and real-time information accessibility. The use of these digital tools contributes to increased operational efficiency, fraud detection and prevention, and strengthened regulatory compliance mechanisms.

Despite these advantages, the review also sheds light on critical barriers to adoption, including high implementation costs, insufficient digital literacy among agricultural stakeholders, and infrastructural limitations, particularly in rural and developing regions. Moreover, the analysis reveals a notable research imbalance, with agricultural auditing receiving considerably less academic attention compared to accounting practices.

This study highlights substantial research gaps and suggests future directions, including the development of technological implementation frameworks, digitally integrated audit models, and heightened focus on cybersecurity risks associated with digital financial ecosystems in agriculture. The review contributes to the growing discourse on digital agriculture, offering valuable insights for policymakers, practitioners, and researchers aiming to enhance financial transparency, accountability, and sustainability in the Agri-financial sector.

Keywords: Digital Agriculture, Agricultural Accounting, Agricultural Auditing, Blockchain, Internet of Things (IoT), Artificial Intelligence (AI), Cloud Computing, Financial Transparency, & Digital Transformation.

ROLE OF POTASSIUM, ZINC, AND BORON APPLICATIONS IN MODULATING COTTON PHENOLOGY UNDER VARIABLE ENVIRONMENTAL CONDITIONS

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ABSTRACT

Cotton phenology is highly sensitive to different temperature regimes, and little work has been conducted to compare the effects of different temperature regimes and nutrients spray at three reproductive stages of cotton (squaring, flowering and boll formation) under field conditions. In this experiment, the three reproductive stages were exposed to the high, medium and optimal temperatures of April, May and June thermal regimes under field conditions. One day prior to the onset of heat stress, potassium at 1.5%, zinc at 0.2% and boron at 0.1% was applied as foliar at three reproductive stages of cotton. Results showed that the April (early) thermal regime took 24% and 33% more days to flowering (DF) over May (normal) and June (late) thermal regimes, respectively while May thermal regime took 7% more time to DF over June sowing date. Similarly, April thermal regime took more days to squaring (DS) and boll splition (DBS) over May and June thermal regimes while May sown crop took more DS and DBS over the June sown crop. Among nutrients, both K and Zn (averaged across) reduced 4, 6 and 8 days to DS, DF and DBS, respectively under April (early) sown crop over the water and boron treated plants (averaged across) of respective thermal regime. However, all nutrients showed non-significant effects on DS, DF and DBS under normal and late sown crops over the water sprayed plants of respective sowing dates. The results concluded that the early sown crop took more DS, DF and DBS over the normal and late sown crops. Among the nutrients, both K and Zn (averaged across) reduced the DS, DF and DBS under early sown crops.

Keywords: Foliar spray, *Gossypium hirsutum*, lint yield, macro and micro nutrients, crop earliness, seed yield

THE KNOWLEDGE, ATTITUDES, AND PRACTICES (KAP) OF POULTRY FARMERS TOWARDS THE USE OF COMMON DISINFECTANTS IN NSUKKA L.G.A OF ENUGU STATE

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ABSTRACT

This study explored the knowledge, attitudes, and practices (KAP) of poultry farmers in Nsukka LGA, Enugu State of Nigeria, toward the use of disinfectants. The findings gave critical insights into the interplay between farmers' awareness of use of disinfectants and associated biological risks, decision-making patterns in the choice of disinfectants, and disinfection practices as they relate to biosecurity. A cross-sectional survey design was employed, targeting 150 purposively selected poultry farms across Nsukka LGA. Data were collected through a structured, close-ended questionnaire validated by the *Department of Veterinary Public Health, University of Nigeria, Nsukka, Enugu state of Nigeria*. Copies of the questionnaire were thereafter distributed to farmers. The questionnaire covered six key areas: socio-demographic information, poultry management, health concerns, knowledge of disinfectants, attitudes towards their use, and practical application. Descriptive statistics, such as frequencies and percentages were used to analyze the data. Inferential statistics, Chi-square test, was employed to assess the statistical associations between the categorical variables. The p-value, $p < 0.05$ was considered statistically significant.. Summary of findings are as follows: **Demographic information** (Majority of farmers (54.7%) are aged 35-50, 38.7% are less than 35years, while 6.7% are above 50years. Most farmers (48%) have secondary education, followed by tertiary education (36.7%) and primary education (15.3%). **Knowledge of Disinfectants:** Generally, the farmers do not know the different classes of disinfectants that they use. They only gave names. From their responses, we were able to classify the various disinfectants they use. Phenolic compounds are the most widely used (19.0%). Acids is lower, with 5.4%. Quaternary ammonium compounds 2.7%, iodine compound is 2.0%. Aldehydes, alcohols, and per-oxygen compounds, each have limited use (1.4%), and chlorine compounds and bases are the least used, with only 0.7%. About 47.6% of respondents use more than one disinfectant. **Awareness of biological risks:** Only 19.5% are fully aware of these risks, while 63.1% have moderate awareness and 17.4% lack awareness entirely. The most commonly recognized disinfectant types are bactericidal (38%) and bactericidal + virucidal (36.7%), while knowledge of fungicidal and sporicidal disinfectants is very low (1.4% each). **Choice determinants:** Cost and availability are the major determinants influencing disinfectant choice, with 34% of farmers considering both factors together. **Practice of Disinfectant Use**: The primary reasons for disinfectant use are disease prevention (22.7%) and cleaning & sanitation (50.7%), most farmers use disinfectants as needed (56.7%), with only 29.3% practicing daily disinfection. Only 6.7% and 7.3% of farmers disinfect their farms weekly and monthly respectively. Significant associations exist between KAP and factors like age ($p = 0.001$ for purpose), education ($p = 0.049$ for expiry checks), and training ($p = 0.003$ for frequency of use) and this underscores the influence of experience and education on biosecurity. **Source of disinfectant recommendation**: Veterinary doctors (61.1%), are the most influential source of disinfectant recommendations, followed by fellow farmers (36.2%). In conclusion, the findings provide critical insights into the gaps in knowledge

and improper disinfectant use, emphasizing the need for targeted education and improved biosecurity measures to enhance poultry health and productivity in the region.

Keywords: Poultry farmers, Disinfectants, Knowledge, Attitudes, Practices, Nsukka.

CREDIT ACCESSIBILITY AMONG MAIZE FARMERS IN IDO LOCAL GOVERNMENT AREA OF OYO STATE, NIGERIA

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ABSTRACT

This study investigates credit accessibility among maize farmers in Ido Local Government Area of Oyo State, Nigeria. A multi-stage sampling technique was employed to select 100 respondents. Data were collected using structured questionnaires and analyzed with both descriptive statistics (frequency, percentage, mean, and standard deviation) and inferential statistics (Chi-square analysis). Findings revealed that the majority of respondents (53.0%) were male, with 46.0% aged between 41–50 years. Most were married (83.0%) and had 1–6 years of formal education (66.0%). Household sizes ranged mainly from 5–8 members (60.0%), and 44.0% had artisan work as a secondary occupation. A substantial number (84.0%) were members of agricultural cooperative societies, and 43.0% acquired farmland through inheritance. Nearly half (49.0%) cultivated 6–10 hectares, and 47.0% had 1–10 years of farming experience. Most respondents (75.0%) had 1–3 contacts with extension agents annually, while 73.0% sourced capital through bank loans. Annual income for 45.0% of respondents ranged between ₦200,001–₦500,000, and 56.0% borrowed less than ₦200,000. Key sources of credit included the Bank of Industry (mean = 2.19), commercial banks (mean = 2.15), and international grants (mean = 2.12). Credit was primarily utilized for purchasing farm tools (mean = 2.19), acquiring farm inputs (mean = 2.15), and expanding maize farming activities (mean = 2.12). Non-agricultural uses included vehicle acquisition for family use (mean = 1.91) and debt repayment (mean = 1.90). Major constraints to credit access were delays in loan processing (mean = 2.43), inadequate collateral (mean = 2.41), and lack of information on credit facilities (mean = 2.34). The study concludes that maize farmers in the study area face significant barriers to accessing credit. It recommends that financial institutions streamline loan processing, ease collateral requirements, and improve information dissemination to enhance farmers' access to financial resources.

IRON ENRICHED JAM USING NATURAL SWEETENER: A SUSTAINABLE FOOD APPROACH

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ABSTRACT

Sustainable food systems emphasize nutrient-rich, eco-friendly alternatives to processed foods. Palmyra jaggery (Borassus flabellifer), a minimally processed, iron-rich natural sweetener, serves as a sustainable substitute for refined sugar. Unlike sugarcane, which requires excessive water and depletes soil, palm trees conserve water, improve soil fertility, and grow without deforestation. This study develops an iron-rich jam using Palmyra jaggery and evaluates its sensory properties, total soluble solids (TSS), moisture content, and shelf-life stability over four months. Jams were formulated with varying Palmyra jaggery proportions. A nine-point hedonic scale assessed taste, texture, aroma, and color. TSS and moisture content were analyzed, and shelf life was monitored under refrigerated conditions. Results showed high sensory acceptability, with minimal texture hardening and slight color darkening over time. Stability analyses confirmed a four-month shelf life without preservatives. Palmyra jaggery enhances nutritional value, sustainability, and economic feasibility by reducing dependence on resource-intensive sweeteners. Standardizing processing methods can further improve quality, reduce spoilage, and support farmer livelihoods. This study underscores the potential of Palmyra jaggery in commercial functional food production, supporting sustainable agriculture and providing an iron-rich alternative to conventional jams for health-conscious consumers.

Keywords: Iron-rich jam, Palmyra jaggery, Sensory evaluation, Shelf-life stability, Sustainable food system

INTERRELATION AMONG HALAL MEAT, MEAT PRODUCTS AND TOURISM SECTOR IN ASIAN CONTINENT

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ABSTRACT

Travelling different places and consuming halal meat, foods, drinks is common practices in Muslim's. The Global Muslim Travel Index (GMTI) projects that over 230 million Muslim travelers will contribute USD 300 billion for the global economy. Muslim's population growth rate is really high. So, Muslim's and non-Muslim's country focus on halal tourism as well as halal food. Dedicated Muslim's views are consuming halal meat as a religious significance, attributing spiritual depth to it. But not all kind of animal meat is halal. Varying different kind production process halal meat can be non halal and also fear of adulteration issue. Facing those problem Muslim tourists are confused with halal meat which also effect on tourism sector. According to Islamic law animal rearing, feeding, management, processing products need to be permissible way. Then the meat and meat products will be halal. Different Muslim's country follows different halal production process and logo for different food items. Non-Muslim's country adapts nearby Muslim's countries system or they follow their own system. Both countries have government or private sector which monitor the whole halal meat and food sector. The marketing system of halal meat of those countries are more or less same. There is a huge possibility to export halal meat to different country. As the growing Muslim population, the halal industry will grow more in future. With government intensive exporting opportunity will rise few times higher than now. As halal foods are mandatory for Muslim's so halal meat, meat products and tourism are related to one another.

Keywords: halal meat, meat products, adulteration, ceritificate bodies, halal logo, halal market, Asia

GAS CHROMATOGRAPHY IN FOOD ANALYSIS

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ABSTRACT

Gas chromatography (GC) is a sophisticated analytical technique that separates and identifies volatile substances in a mixture using a mobile gas phase and a stationary phase, allowing for both qualitative and quantitative analyses. The purpose of this article is to provide a quick overview of the many applications of GC in food analysis in comparison to high-performance liquid chromatography (HPLC), as well as to discuss cutting-edge GC techniques utilized in the most common applications.analysis of food is required for several reasons, including detection of harmful components, monitoring legislation, detecting adulteration, formulation of controlled diets, managing formulation throughout product development and detecting changes in food during storage and processing . Finally, GC's high sensitivity, selectivity, and adaptability make it an invaluable tool for ensuring the safety of food supplies. As food analysis evolves, GC will remain an important tool for protecting consumers and maintaining the highest standards of food quality.One of the primary advantages of GC is its ability to handle complicated mixtures with precision, making it important in quantitative and qualitative analysis. Furthermore, combining GC with mass spectrometry (GC-MS) improves identification capabilities by providing structural information about analytes. However, GC is confined to thermally stable and volatile molecules, making it unsuitable for nonvolatile or strongly polar chemicals. Despite these limitations, gas chromatography is a fundamental component of analytical chemistry, providing unparalleled efficiency in chemical separation and analysis across a wide range of scientific disciplines.

Keywords : Gas chromatography, Food analysis , Qualitative, sensitivity and techniques.

PARENTING STYLE AND NUTRITION: A CROSS-CULTURAL SYNTHESIS OF EVIDENCE ON FEEDING PRACTICES AND DIETARY OUTCOMES

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ABSTRACT

Background:

Parenting style is an important but neglected determinant of children's dietary behaviors. Despite the fact that authoritative parenting has been found to be the most beneficial to healthy eating in western literature, this paradigm needs to be examined within the culturally diverse environment of Asia.

Objective:

To synthesize current research on how parenting styles (authoritative, authoritarian, permissive and neglectful) influence children's dietary outcomes in different Asian cultural settings.

Methods:

A narrative review was conducted by analyzing 23 peer-reviewed studies published between 2015 and 2025. Studies were selected based on the use of Baumrind's parenting framework and their focus on dietary behaviours of Asian or Asian diaspora populations. PubMed, Scopus and Google scholar were used to draw data of the paper and assessed for the cultural relevance, methodological soundness and nutritional outcomes.

Results:

The findings suggests that authoritative parenting, consistently, is associated with better dietary behaviors like higher fruit and vegetable intake, more structured mealtimes, and lower obesity risk. Nevertheless, there are cultural factors that modify the interpretation of parenting styles: authoritarian attributes can be interpreted as care and responsibility in collectivist societies. Some poor dietary habits were linked with non-responsive styles in particular permissive and neglectful. Disordered eating regardless of style resulted from such feeding practices as coercion or emotional feeding. Outcomes were also significantly influenced by parental education, stress and socio-economic status.

Conclusion:

Although Authoritative parenting has cross-cultural applicability, culturally sensitive adaptations of parenting are needed for effective public health interventions in Asia. Parenting support programs geared specifically toward the context can improve childhood nutrition.

Keywords: Parenting styles, child nutrition, feeding practices, authoritative parenting, Asia, cultural adaptation

THE IMPACT OF NaOH PRETREATMENT, THERMAL PRETREATMENT, AND THEIR COMBINATION (NaOH-thermal) ON BIOMETHANE YIELD DURING THE ANAEROBIC DIGESTION OF WALNUT SHELLS

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ABSTRACT

Anaerobic digestion (AD) of walnut shells (WS) produces limited biomethane yields due to their high fiber content, classifying them as a largely non-biodegradable lignocellulosic biomass. In this study, thermal pretreatment (50–250 °C), alkaline pretreatment (1–5% w/w NaOH), and a combined alkaline-thermal approach (4% w/w NaOH + 150 °C) were evaluated to enhance the anaerobic biodegradability of WS. The highest biomethane yields, 159.9 ± 6.8 mL CH_4.g VS^{-1} and 169.8 ± 6.8 mL CH_4.g VS^{-1}, were obtained following thermal pretreatment at 250 °C and NaOH pretreatment at 4%, respectively. The combined NaOH-thermal pretreatment resulted in the highest biomethane yield of 192.4 ± 8.2 mL CH_4.g VS^{-1} at the end of the AD process, although it exhibited the longest lag phase (3.90 days) and the highest total VFA concentration (1280.1 mg HAc L^{-1}). This superior yield was supported by the highest SCOD/TCOD ratio (0.37 ± 0.02) and the most effective removal of lignocellulosic fibers, with reductions of 41.1 ± 2.7% in cellulose, 35.6 ± 1.8% in hemicellulose, and 58.7 ± 3.2% in lignin. Cumulative biomethane production was successfully modeled using a modified Gompertz equation. This study highlights that thermal, NaOH, and combined NaOH-thermal pretreatments are effective strategies for significantly improving the biomethane yield of WS, even with their high lignin content.

Keywords: Alkaline pretreatment . Biomethane production . Thermal pretreatment, Lignocellulosic removal . Lignocellulosic biomass . Biogas . Alkaline-thermal pretreatment.

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ANTIBIOTIC SUSCEPTIBILITY PATTERN OF BACTERIA ASSOCIATED WITH HAWKED SUYA-MEAT IN ALIERO METROPOLIS

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ABSTRACT

Meat is the flesh of animals which serves as food and it is obtained from sheep, cattle, goat and swine. It is that part of animal that provides major source of protein in West African food. The aim of this research is to isolate and identify bacteria associated with hawked Suya meat in Aliero metropolis and to determine antibiotic susceptibility pattern of bacteria. Suya meat were bought from the sellers and was collected in raps of Aluminum foil. It was then taken to the laboratory for analysis. The sample was homogenized and pipetted using 5ml sterile pipette. This was cultured on Mackonkey agar and Nutrient agar incubated at 37^0C for 24 hours. Discrete bacteria colonies were observed and each colony was gram-stained and examined microscopically. Biochemical identification were carried out to confirm the particular bacteria present. The disc diffusion assay was employed to investigate the sensitivity of isolates to the antibiotics. The standardized inocula of the test organisms were emulsified on the surface of Mueller-Hinton agar using sterile cotton swab, the plates was dried at room temperature for 5 min, and incubated at 30^0C for 48 hours. The following antibiotic discs at different concentrations were used: Septrin (SXT) 30µg, Streptomycin (S) 30µg, Chloramphenicol (CH) 30µg, Sparfloxacin (SP) 10µg, Amoxicillin (AM) 30µg, Ciprofloxacin (CPX) 10µg, Tarivid (OFX) 30µg, Gentamycin (GN) 10µg, Pefloxacin (PEF) 10µg and Augumetin (AU) 25µg.Bacteria isolated were *Staphylococcus aureus, Bacillus subtilis* and *Escherichia coli.*The result of this research provides preliminary data on bacteria contamination of Suya meat such as *Staphylococcus aureus, Bacillus spp* and *Escherichia coli.* Awareness as regard to hygiene should be created to the sellers to minimize the rate of contamination through carelessness. If suya meat must be hawked, it should be carried about in protective glass case or ware that does not expose it to microorganisms as to reduce the incidence of food poisoning in the society.

Keywords; Meat, Antibiotic, Bacteria, Sensititivity, Suya.

MITIGATION OF SALINITY INDUCED NEGATIVE EFFECTS ON THE GERMINATION AND GROWTH OF SOYBEAN BY CALCIUM APPLICATION

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ABSTRACT

Soybean is an oil seed leguminous crop and moderately sensitive to salt stress. The response of soybean plant to salt stress depends heavily on the Salt Overly Sensitive (SOS) signaling system. The present study outlines how calcium treatment may help reduce salinity stress and affects soybean seed germination and growth parameters. The seeds of two contrasting varieties (salt tolerant and salt sensitive) were primed with different concentrations of calcium (10 and 20 mM) and stressed with different levels of NaCl (80 and 100 mM). The findings indicate that while germination improved by up to 25% under NaCl stress, it was enhanced by 7% in calcium primed, unstressed seeds under non-stressing conditions. Similarly, in calcium-primed plants, improvements in seedling length (8%), plant height (18%), number of nodes (14%), SOD activity (20%), and Na^+/K^+ concentration (5% reduction) show that the adverse effects of salinity have been reduced. Furthermore, the presence of orthologs of the *Arabidopsis thaliana SOS* genes in soybeans was confirmed and identified *in silico* in this study. The *Glycine max* genome's amino acid sequences of SOS proteins from *Arabidopsis thaliana* (AtSOSs) showed up to 80% protein identity; as a result, these homologs were known as *GmSOS*. Additional phylogenetic and in silico analyses revealed that GmSOSs are members of the SOS family and may have similar functions because they share many characteristics with orthologs from other species. This is the first study to describe how SOSs help soybeans cope with salt stress.

HEMATOLOGICAL AND BIOCHEMICAL ALTERATIONS INDUCED BY DELTAMETHRIN EXPOSURE IN MALE

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ABSTRACT

Deltamethrin has been reported to induce toxic effects in various organs of both mammalian and non-mammalian species. In this study, rats were divided into two groups: a control group (n=3) that received no treatment, and a treated group (n=6) that was administered deltamethrin. Hematological and biochemical parameters were analyzed to assess the toxicological impact. The results showed a highly significant increase in white blood cell (WBC) count (p=0.001) and a significant change in red cell distribution width-standard deviation (RDW-SD) (p=0.026) in the treated group compared to the control. No significant differences were observed in hemoglobin (Hb), red blood cells (RBCs), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), RDW-CV, platelet count (Plt), mean platelet volume (MPV), platelet distribution width (PDW), or plateletcrit (PCT). Biochemical analysis revealed highly significant elevations in Gamma-Glutamyl Transferase (GGT) (p=0.001) and aspartate aminotransferase (AST) (p=0.003), along with significant increases in urea (p=0.024) and uric acid (UA) (p=0.037). No significant changes were detected in total, direct, or indirect bilirubin, alkaline phosphatase (ALP), alanine aminotransferase (ALT), or creatinine (CREA) levels. These findings suggest that deltamethrin induces selective hematological and biochemical alterations, indicating its potential toxic effects.

Keywords: Deltamethrin, Toxicity, Hematological parameters, Biochemical parameters, Rats, Insecticide exposure

LI-FI BASED INDOOR NAVIGATION SYSTEM

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ABSTRACT

Localization and navigation systems are practically viable and can easily be used but are not commonly used in real-time. In this presentation, an indoor navigation and information system that is easy to implement and use has been proposed, that uses visible light communication (VLC), which is an ideal technology for an application like this. The proposed system focuses on designing a device for visually impaired people that is comfortable, user-friendly, and also helps them travel independently.

This system aims to provide location information in the absence of explicit instructions and can be a supporting method for users who travel in buildings. The LiFi technology enhances indoor navigation by providing precise location updates via a Li-Fi transmitter, receiver, and Arduino microcontroller. Tested under varying conditions, it aids visitors in navigating buildings where directions are unclear.

For visually impaired individuals, Li-Fi-based navigation offers real-time positional data and guidance through audio output, addressing challenges in public spaces. The system includes LED lights transmitting positional info and an embedded receiver that calculates optimal paths.

REPRESENTATIONS OF KURDISH WOMEN IN TRADITIONAL MEDIA: THE CASE OF TRT KURDI AND YEREVAN RADIO

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ABSTRACT

Kurdish broadcasting activities and traditional radio broadcasting activities began in 1939 with Baghdad Radio. The suitability of the conditions of the period and the difficulty women had in getting involved in occupational health within the patriarchal order, Baghdad Radio became an important milestone in Kurdish women's introduction to radio broadcasting activities. Following Baghdad Radio, Yerevan Radio, which was established in Armenia in 1955, spread to surrounding geographies and was considered an important traditional media representation for Kurds. In this research, the conditions of the period were taken into consideration, the patriarchal order within the specified geography was examined, and the possibility of mobbing that could be applied to women employees was emphasized. Within the scope of the research, the working conditions of women media employees working at Yerevan Radio and the working conditions of women media employees working under TRT Kurdi today are met. As a result of this comparison, the representative power produced by traditional women and the comprehensive working conditions in the past will be examined between the past and the present. Enziva Reşit, who was a presenter at Yerevan Radio, which continued its broadcasting life within the patriarchal order brought by the conditions of this period, is the first Kurdish female presenter, and the first Kurdish radio and television channel established in the state, TRT Kurdi, are generally evaluated.

While making this comparison, the studies conducted on Yerevan Radio, in addition to the negotiations conducted with Temur Muradov, the son of Enziva Reşit; the documents obtained regarding TRT Kurdi radio and television have content analysis technology. The comparisons obtained in the interview conducted with TRT Kurdi presenter … using a part-time interview machine are between for the purpose of comparison.

As a result of these comparisons, it was revealed that, apart from the oppressive policies presented by the Cold War Period in the case of Yerevan Radio, Enziva Reşit was accepted in society almost equally with today's TRT Kurdi female media people.

Keywords: TRT, ERIVAN, PRESENTER, WOMAN

KÜRT KADINLARIN GELENEKSEL MEDYADAKİ TEMSİLLERİ: TRT KURDİ VE ERİVAN RADYOSU ÖRNEĞİ

ÖZET

Kürt dilinde yayın faaliyetleri ve geleneksel radyoculuk çalışmaları 1939 yılında Bağdat Radyosu ile başlamıştır. Dönemin şartları gereği ataerkil düzen içerisinde, kadınlar iş hayatına atılmada zorluk yaşasa da, Bağdat Radyosu Kürt kadınlarının radyoculuk faaliyetleriyle tanışmasında önemli bir mihenk taşı olmuştur. Bağdat Radyosunu takiben 1955 yılında Ermenistan'da kurulan Erivan Radyosu çevre coğrafyalara yayılmış Kürtler için, önemli bir geleneksel medya temsili olarak kabul edilmekteydi.

Bu araştırmada, dönem şartları göz önüne alındığında, belirtilen coğrafyanın içerisinde bulunduğu ataerkil düzen bağlamında, kadın çalışanlara karşı uygulanabilecek mobbing ihtimali üzerinde durulmuştur. Araştırma kapsamında, Erivan Radyosu'nda görev alan kadın medya çalışanlarının çalışma şartları ile günümüzde TRT Kurdi bünyesinde görev alan kadın medya çalışanlarının çalışma şartları karşılaştırılmaktadır. Bu karşılaştırma neticesinde geçmiş ile günümüz arasında, geleneksel medyada kadının değişen temsil gücü ve geçmişten günümüze çalışma koşulları incelenecektir. Bu çerçevede dönem şartlarının getirdiği ataerkil düzen içerisinde yayın hayatına devam eden Erivan Radyosu'unda spikerlik yapan Enziva Reşit, ilk Kürt kadın spikeri, ve devlet eliyle kurulan ilk Kürt radyo ve televizyon kanalı olan TRT Kurdi çalışmanın örneklemi olarak seçilmiştir.

Bu karşılaştırma yapılırken Erivan Radyosu ile ilgili yapılmış çalışmalara ek olarak Enziva Reşit'in oğlu Temur Muradov ile yapılan mülakat; TRT Kurdi radyo ve televizyonu ile ilgili edinilmiş dokümanlar içerik analizi tekniği kullanılarak incelenmiştir. TRT Kurdi sunucusu … ile yarı yapılandırılmış görüşme tekniği kullanılarak yapılan mülakatta edinilen bulgular karşılaştırma amacı ile incelenmiştir.

Bu karşılaştırmalar neticesinde, Erivan Radyosu örneğinde Soğuk Savaş Dönemi'nin getirdiği baskıcı politikalar haricinde, Enziva Reşit'in ilk Kürt Kadın spiker olarak, günümüz TRT Kurdi kadın medyacıları ile neredeyse eşit şekilde toplumda kabul gördüğü ortaya çıkmıştır.

Anahtar kelimeler: TRT, ERİVAN, SUNUCU, KADIN

OTOMAN POLITICS AND MILITARY DEVELOPMENTS FROM SULTAN OSMAN III TO SULTAN SELIM III: AN EVALUATION FROM THE PERSPECTIVE OF THE 18TH CENTURY

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ABSTRACT

This study analyzes the transformation in the domestic and foreign policies of the Ottoman Empire during the second half of the 18th century, specifically focusing on the period from Sultan Osman III to Sultan Selim III. This era was marked by significant internal and external upheavals, which forced the empire into a process of change. Domestically, the frequent changes in grand viziers reflected growing political instability and weakened administrative control. These changes were not merely the result of palace intrigues but were symptomatic of broader structural issues within the Ottoman governance system.

Externally, the empire engaged in prolonged conflicts and diplomatic relations with major powers such as Russia, Austria, and Iran. These interactions, through wars and treaties, deeply influenced the formulation and adaptation of Ottoman foreign policy. The military setbacks and territorial losses emphasized the need for urgent reform in both military and administrative institutions.

This paper particularly emphasizes the reform efforts initiated under Sultan Selim III, who, unlike his predecessors, actively pursued structural modernization through initiatives such as the Nizam-ı Cedid (New Order). However, these reforms were also met with resistance, highlighting the tension between innovation and tradition within the Ottoman elite.

By offering a comparative evaluation of the political and military developments under the reigns of Sultan Osman III and Sultan Selim III, this study seeks to contribute to a deeper understanding of the Ottoman Empire's gradual transformation during a critical phase in its history. The findings also provide insight into how reform efforts were shaped by both internal dynamics and external pressures.

Keywords: Ottoman History, 18th Century, Political Reforms.

THE COMPREHENSIVE HORIZON OF ARTIFICIAL INTELLIGENCE IN VETERINARY MEDICINE

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ABSTRACT

AI's influence on veterinary medicine goes beyond documentation, bringing with it a new era of technology integration that affects all facets of veterinary practice. AI's adaptability is demonstrated by its use in numerous crucial fields, which is revolutionising not just the way data is captured but also the methods used for diagnosis, treatment, and training in those fields.

AI systems are able to scan through large databases of research findings and clinical records to provide recommendations for a diagnosis based on past data and symptoms. This capacity helps veterinarians create differential diagnoses and anticipate possible consequences, which helps them develop the best treatment strategies. In a field where a wide range of species and conditions are encountered, such diagnostic assistance is crucial.

One of the many uses for AI is as a tool for SOAP notes. A brief summary of many software businesses that are doing intriguing things is also included in this article: Shepherd, Instinct, Vetsoap, and PetDesk.

Keywords: Artificial Intelligence, Software, Veterinary medicine, diagnostic medicine

DIGITAL TRANSFORMATION IN THE INSURANCE INDUSTRY: INSURTECH

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ABSTRACT

With the developments in internet usage and information technologies, technology-focused innovations have started to increase in the finance sector. In particular, applications such as the internet of things, artificial intelligence, robotic technologies, machine learning, data analytics, autonomous vehicles, 3D printers, and blockchain have accelerated digital transformation in the finance sector. Digital transformation is a concept that refers to the integration of business processes with newly developed digital technologies. Digital transformation has paved the way for financial technology (fintech) companies to provide more services in the sector. In addition, Insurtech, which develops technologies for the insurance sector among fintech companies and includes them in various aspects of the sector, has become an important concept that has come to the fore in recent years. Insurtech is a concept created by abbreviating the words “Insurance” and “Technology” and includes technologies applied in the field of insurance. The concept of Insurtech refers to an innovative information system that emerges through the process of intensively integrating technology into insurance-related activities. Insurtech digitizes and automates insurance processes such as policy purchase, risk management, premium determination and damage-compensation payments, making transactions faster and more efficient. In addition, Insurtech uses technology to facilitate product comparison, simplify the purchasing process, and better adapt insurance coverage, as well as to increase efficiency, developing innovative business models that can provide policyholders with greater insurability. In emerging markets with less developed distribution networks, insurtech has the potential to improve financial inclusion and increase insurance penetration. Although Insurtech has the potential to provide great benefits for both insurers and end users, it also includes risks such as cybersecurity and technology risk management. Insurtech investments, which started to develop in the global insurance sector in 2011, are increasing day by day. This study aims to examine in detail the Insurtech investments that will transform the insurance sector. In this context, the development process, advantages, disadvantages of Insurtech, its status in the world and in Turkey are examined in the study, and some suggestions are presented for the future development of Insurtech.

Keywords: Digital Transformation, Fintech, Insurtech

AN EXAMINATION OF LIFE ORIENTATION IN ADULTS WORKING WITH INDIVIDUALS WITH SPECIAL NEEDS

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ABSTRACT

In this study, the relationships between the life orientation of young adults working in rehabilitation centers and their socio-demographic characteristics were examined. The research is a descriptive study designed using the relational screening model, with the participation of young adults working in rehabilitation centers. The sample of the study consists of 300 young adults employed at rehabilitation centers. In order to collect data, a Socio-Demographic Information Form and the Life Orientation Test-Revised (LOT-R) were used. The data collected for the study were analyzed using the SPSS program. For data analysis, t-test, Pearson correlation analysis, Analysis of Variance (ANOVA), and Regression Analysis methods were employed. According to the findings obtained from the study, a moderate, positive, and significant relationship was found between life orientation and educational level among young adults working in rehabilitation centers. This result indicates that as the level of education increases, the level of life orientation (optimism) also increases. A low-level, negative, and significant relationship was also found between life orientation and years of work experience. This finding shows that as the number of years worked increases, the level of life orientation (optimism) decreases. It was found that there is no significant difference in life orientation between young adult women and men working in rehabilitation centers. No significant difference in life orientation was found between age groups (19–24 years and 25–34 years). However, when comparing single and married young adults working in rehabilitation centers, a significant difference in life orientation was found between the groups. The average life orientation of single individuals was found to be significantly higher than that of married individuals. Additionally, the average life orientation of young adults without children was found to be significantly higher than that of those with children.

Keywords: Life Orientation, Optimism, Rehabilitation Centers, Young Adults.

ÖZEL GEREKSİNİMLİ BİREYLERLE ÇALIŞAN YETİŞKİNLERDE YAŞAM YÖNELİMİNİN İNCELENMESİ

ÖZET

Bu çalışmada; rehabilitasyon merkezlerinde çalışan genç yetişkinlerin yaşam yönelimleri ile sosyo-demografik özellikleri arasındaki ilişkiler incelenmiştir. Araştırma rehabilitasyon merkezlerinde çalışan genç yetişkinlerin katıldığı ilişkisel tarama modelinin kullanıldığı betimleyici nitelikte bir çalışma tasarımındadır. Araştırmanın örneklemini rehabilitasyon merkezlerinde çalışan 300 genç yetişkin oluşturmaktadır. Araştırmada veri toplamak amacıyla; Sosyo-Demografik Bilgi Formu ve Yaşam Yönelimi Testi (YYT-R) kullanılmıştır. Araştırma için toplanan veriler SPSS programıyla analiz edilmiştir. Verilerin analizi için t Testi, Pearson korelasyon çözümlemesi, Varyans Analizi (ANOVA) Testi ve Regresyon Analizi yöntemleri kullanılmıştır. Araştırmadan elde edilen bulgulara göre; Rehabilitasyon merkezlerinde çalışan genç yetişkinlerde yaşam yönelimi ve eğitim düzeyi arasında da orta düzeyde, pozitif ve anlamlı bir ilişki bulunmuştur. Bu sonuçlar, eğitim düzeyi arttıkça yaşam yönelimi (iyimserlik) düzeyinin de arttığı anlamına gelmektedir. Yaşam yönelimi ve çalışma yılı arasında da düşük düzeyde, negatif ve anlamlı bir ilişki bulunmuştur. Bu bulgu, çalışma yılı arttıkça yaşam yönelimi (iyimserlik) düzeyinin azaldığını göstermektedir. Rehabilitasyon merkezlerinde çalışan genç yetişkin kadınlarla, rehabilitasyon merkezlerinde çalışan genç yetişkin erkeklerin yaşam yönelimi bakımından anlamlı olarak farklılaşmadığı bulunmuştur. Yaş grupları (19-24 yaş ve 25-34 yaş) arasında yaşam yönelimi bakımından anlamlı fark olmadığı bulunmuştur.Rehabilitasyon merkezlerinde çalışan bekar genç yetişkinlerle, evli genç yetişkinler karşılaştırıldığında yaşam yönelimi bakımından gruplar arasında anlamlı fark elde edilmiştir.Yaşam yönelimi bakımından bekarların ortalaması evlilerden anlamlı olarak daha yüksek olduğu tespit edilmiştir.Rehabilitasyon merkezlerinde çalışan genç yetişkinlerden çocuğu olmayanların yaşam yönelimi ortalaması ise çocuğu olanların yaşam yönelimi ortalamasından anlamlı olarak daha yüksek olduğu belirlenmiştir.

Anahtar Kelimeler: Yaşam Yönelimi,İyimserlik,Rehabilitasyon Merkezleri,Genç Yetişkinler.

THE RELATIONSHIP BETWEEN FINANCIAL WELL-BEING AND PSYCHOLOGICAL BURNOUT: AN EMPIRICAL RESEARCH

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ABSTRACT

There are many factors that can disrupt human psychology today. These factors can be listed as internal and external factors. One of the external factors and the ones that are thought to have the greatest impact is the financial situation. Living conditions and socioeconomic opportunities resulting from developments in the world are decreasing day by day and making life difficult. Insufficient income and financial opportunities in the face of increasing needs and expenses cause people to have difficulty balancing their income and expenses, and in this case, they do not feel good psychologically.

The purpose of this research is to reveal the relationship between the financial well-being of households and their psychological burnout. The universe of the research is the financial consumer 461 of households in Bingöl province. First of all, the Cronbach Alpha coefficient of the Financial Well-Being and Burnout scale was calculated in the research. The alpha coefficient was found to be 0.83. When it is considered in terms of research conducted in the field of social sciences, it can be said that the relevant values are highly reliable. The data obtained from the survey were evaluated using the SPSS 22.0 package program and the test tests were conducted by taking into account the 5% significance level.

When the distribution of households according to demographic characteristics is examined, it is determined that women, those in the 18-22 age group and singles are in the majority. When the household is examined in terms of education, occupational status and income level, it is determined that university students, students and those in the income group of less than 10,000 TL are in the majority.

The normal distribution status of the scale scores was tested with the skewness test. It was determined that the Financial Well-being and Burnout scales showed a normal distribution. Pearson correlation was used in the relationship between the scales. A positive relationship was found between financial well-being and psychological burnout.

Keywords: Financial well-being, psychological burnout, household

FİNANSAL İYİLİK HALİ İLE PSİKOLOJİK TÜKENMİŞLİK ARASINDAKİ İLİŞKİ: AMPİRİK BİR ARAŞTIRMA[1]

ÖZET

Günümüzde insan psikolojisini bozacak çok fazla faktör mevcuttur. Bu faktörler iç ve dış etkenli faktörler olarak sıralanabilir. Dış faktörlerden ve en büyük etkisinin olduğu düşünülenlerden biri de finansal durumdur. Dünyadaki gelişmelerden kaynaklanan yaşam koşulları ve sosyoekonomik imkanlar her geçen gün azalarak yaşamı zorlaştırmaktadır. Artan ihtiyaçlar ve harcamalar karşısında yetersiz kalan gelir ve finansal imkanlar insanların gelir giderlerini dengelemekte zorluklar yaşamalarına neden olmakta ve bu durumda psikolojik olarak kendilerini iyi hissetmemelerine sebebiyet vermektedir.

Bu araştırmanın amacı, hanehalkının finansal iyilik hali ile psikolojik tükenmişlikleri arasındaki ilişkiyi ortaya koymaktır. Araştırmanın evrenini Bingöl ili hanehalkının 461 finansal tüketici oluşturmaktadır. Araştırmada öncelikle Finansal İyilik Hali ve Tükenmişlik ölçeğinin geneline ait Cronbach Alpha katsayısı hesaplanmıştır. Alpha katsayısı 0,83 olarak bulunmuştur. Sosyal bilimler alanında yürütülen araştırmalar açısından bakıldığında ilgili değerin yüksek seviyede güvenilir olduğu söylenebilir. Anketten elde edilen veriler, SPSS 22.0 paket programı kullanılarak değerlendirilmiş ve test sınamaları %5 anlamlılık düzeyi dikkate alınarak yapılmıştır.

Hanehalkının demografik özelliklerine göre dağılımına bakıldığında; kadınların, 18-22 yaş aralığı grubunda olanların ve bekarların ağırlıkta olduğu tespit edilmiştir. Eğitim, mesleki durum ve gelir düzeyi açısından hanehalkı incelendiğinde ise üniversite öğrencilerinin, öğrencilerin ve 10.000 TL'den az gelir grubunda yer alanların çoğunlukta olduğu saptanmıştır.

Ölçek puanlarının normal dağılım durumu çarpıklık (Skewness) testi ile sınanmıştır. Finansal İyilik Hali ve Tükenmişlik ölçeklerinin normal dağılım gösterdiği tespit edilmiştir. Ölçekler arası ilişkide Pearson korelasyonundan yararlanılmıştır. Finansal iyilik hali ile psikolojik tükenmişlik arasında pozitif ilişki tespit edilmiştir.

Anahtar Kelimeler: Finansal iyilik, psikolojik tükenmişlik, hanehalkı

[1] Bu özet bildiri hazırlanmakta olan "Finansal İyilik Hali ile Psikolojik Tükenmişlik Arasındaki İlişki: Hanehalkı Üzerinde Ampirik Bir Uygulama" başlıklı kitap bölümünden türetilmiştir.

CAN FALSE SELF BE FUNCTIONAL?

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ABSTRACT

Self; It expresses awareness regarding the changes that occur in time in terms of personality and is mostly encountered in the literature in two different forms as real self and false self. Real self; It includes reflecting the awareness in question to people as it is. In false self, on the other hand, it is about changing the elements related to this awareness and using these elements by making them loved and accepted by people.

When the literature is examined, in almost all sources; false self appears as an undesirable situation. The aim of this study is to draw attention to the fact that the concept of false self, which is largely considered as an undesirable situation and whose negative aspects are emphasized, can have a positive side and serve a functional purpose.

The literature on the subject has been examined in depth and a compilation study has been presented in this direction. The definition of self, the functions of real and false self have been mentioned. By examining and synthesizing the information obtained from the academic literature, the idea that the concept of false self can be functional has gained weight.

False self; It is formed by feeding on the creativity of the individual and can again serve a function such as supporting that creativity. In addition, when used in moderation, it can serve to protect the integrity of the self, as in defense mechanisms that appear as a protective element of the self. It can increase the person's adaptation to social life in individuals with low self-esteem or psychopathology and provide functionality in daily routines. In order to further clarify this situation; it is useful to look at the correlation of the false self concept with the situations that are thought to have a functional effect.

Keywords: Self, ego, false self.

SAHTE KENDİLİK İŞLEVSEL OLABİLİR Mİ?[1]

ÖZET

Kendilik; kişilik açısından zamanla meydana gelen değişimlere ilişkin farkındalığı ifade etmektedir ve literatürde çoğunlukla; gerçek kendilik-sahte kendilik şeklinde iki farklı biçimde karşımıza çıkmaktadır. Gerçek kendilik; bahsi geçen farkındalığının insanlara olduğu gibi yansıtılmasını içerir. Sahte kendilikte ise bu farkındalığa ilişkin unsurların değiştirilmesi ve bu unsurların insanlar tarafından sevilip-kabul görmeyi sağlayıcı hale getirilerek kullanılması söz konusu olmaktadır.

Literatür incelendiğinde neredeyse tüm kaynaklarda; sahte kendilik pek de istendik olmayan bir durum olarak karşımıza çıkmaktadır. Bu çalışmanın amacı ise; büyük oranda istenmedik bir durum olarak ele alınan ve olumsuz taraflarına dikkat çekilen sahte kendilik kavramının, olumlu bir tarafı olabileceğine, işlevsel bir amaca hizmet edebileceğine dikkat çekmektir.

Konu ile ilgili literatür derinlemesine ele alınmış ve bu doğrultuda bir derleme çalışma ortaya konulmuştur. Kendiliğin tanımı, gerçek ve sahte kendiliğin işlevlerine değinilmiştir. Ulaşılan akademik yazından elde edilen bilgilerin incelenip sentezlenmesi ile sahte kendilik kavramının işlevsel olabileceği fikri ağırlık kazanmıştır.

Sahte kendilik; bireyin yaratıcılığından beslenip oluşturulmakta ve yine o yaratıcılığı destekleme gibi bir işlev görebilmektedir. Ayrıca dozunda kullanıldığında benlik bütünlüğünü koruyucu bir unsur olarak karşımıza çıkan savunma mekanizmalarındaki gibi kişinin benlik bütünlüğünü koruma işlevi görebilmektedir. Özgüveni düşük veya psikopatoloji barındıran bireylerde kişinin sosyal hayat adaptasyonunu artırıp günlük rutinler konusunda işlevselliğini sağlayabilmektedir. Bu durumu daha da netleştirebilmek adına; sahte kendilik kavramının işlevsel olarak etki ettiği düşünülen durumlarla korelasyonuna bakılmasında yarar vardır.

Anahtar Kelimeler: Kendilik, benlik, sahte kendilik.

[1] Bu özet bildiri, hazırlanmakta olan "**Sahte Kendilik İşlevsel Olabilir Mi?**" başlıklı kitap bölümünden türetilmiştir.

RELATIONSHIP BETWEEN ANXIETY LEVEL ON ADULTS AND CHILDHOOD TRAUMA AND PARENTAL ATTITUDE

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ABSTRACT

The objective of this research is to examine the relationship between anxiety level on individuals and childhood traumas and parental attitudes. It was also evaluated whether childhood traumas and parental attitudes differ according to demographic variables. Parental Attitude Inventory, Childhood Traumas Questionnaire, Beck Anxiety Inventory were employed on the porpuse of evaluating the relationship between adults' anxiety level and childhood traumas and parental attitudes, Personal Information Questionnaire was applied to gather personal informations of participants.

The study was conducted applying correlation survey model among quantitative methods. It was conducted in 2025 with a sample of 402 adult individuals living in Türkiye, aged between 18-65. Data used in this study was collected online by forms delivered to participant via Google Forms. Collected data on this study was analyzed using SPSS 25 packaged software. Normality assessment, applied on the porpuse of assigning statistical test employing, was conducted considering skewness and kurtosis. Fallowing determination of normal distribution of the data, unpaired t-test, one way Anova, Pearson Correlation, simple and multiple linear regression were employed among parametric test methods. According to obtained information, statistically significant and positive relationship was observed between individual's anxiety level and cildhood traumas ($p<.05$). Negative and significant relationship was observed between adult individuals' anxiety level and democratic parental attitude ($p<0.01$). On the other hand, positive and significant relationship was observed between anxiety level and authoritative parental attitude and protective parental attitude. According to this result, parent's too protective or strict attitude can increase individual's anxiety.

Keywords: Parental attitude, anxiety level, childhood trauma

ANTIMICROBIAL POTENTIAL OF LIVID PIGWEED (*Amaranthus lividus* L.)

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ABSTRACT

Amaranthus L. is a broadly distributed herbaceous genus encompassing around 70 species called pigweeds or amaranths. Because of the synonyms applied to the misidentified names and misapplication of names the species number is still unsettled [1]. A. lividus is an annual, glabrous species reaching heights of 17–40 cm. Fruits are oval shaped and indehiscent. The seeds are 1-1.2 mm in diameter. In Azerbaijani flora it is distributed in Absheron, Kur-Araz lowland, Lankaran and found in riverbanks and roadsides [2]. For the antimicrobial assay the aerial parts and roots of A. lividus were collected during summer of 2024 from the Sabirabad district of Azerbaijan. After being air dried the aerial and underground parts were extracted separately using benzene, chloroform, ethanol, acetone, and distilled water. The antimicrobial activity of all these extracts were evaluated by disc-disffusion test against *Staphylococcus aureus*, MRSA (Methicillin-resistant *Staphylococcus aureus*), *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Bacillus anthracoides* and *Candida albicans*. The acetonic extract of aerial parts demonstrated antibacterial activity against *B. anthracoides* with 10 mm diameter zone of inhibition. Benzene and ethanolic extracts of roots and aerial parts have showed a slightly weak antibacterial activity against *P. aeruginosa* producing a 7 mm zone of inhibition. All investigated extracts have inhibited the growth of *E. coli.* With regards to the *C. albicans* all analyzed extracts have showed an antifungal activity, except those obtained with distilled water. Amongst the tested extracts, the acetonic extract of the roots showed the largenst inhibition zone against MRSA, measuring 10 mm in diameter and 7 mm of it was attributable to the control solution, which was dimethyl sulfoxide. *A. lividus* is used in the treatment of lung disorders, and its use in Ayurvedic medicine has also been reported. Moreover, the presence of phenolics, flavonoid, alkaloids and saponins has been shown in its leaves [3]. The evaluated antibacterial and antifungal activities in this study provide a basis for future research on its phytochemical components and potential use in medicinal and public health fields.

Keywords: disk-diffusion method, microbial growth inhibition, livid pigweed.

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ISLATION AND IDENFICATION OF FUNGAL SPECIES ASSOCIATED WITH THE TIGER NUT DRINK IN SOME TERTIARY INSTITUTION WITHIN KATSINA METROPOLIS.

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ABSTRACT

Tigernut milk drink is a traditional non-alcoholic beverage with a spicy nutty taste. It is widely consume for its nutritional and medicinal benefits to its consumers and for its non-alcoholic properties. A range of microbes can be associated with drink manufactured, though only a few are able to cause spoilage. Microbiological spoilage leads to deterioration of the sensory quality and typically appears as off-flavors, odours and visual changes in the product, The aim of this research is the isolation and identification of common fungi associated with Tigernut milk drink within some tertiary institutions at katsina metropolis. These institutions are located in katsina state.The research followed a laboratory based experimental design were Samples of locally produced tiger nut drinks from these institutions were collected and analyzed for microbial content through the use of PDA media for isolation and identification, the results shows the present of fungal isolated which were dominantly candida spp from the whole samples, it was concluded that presence of fungal isolates can leads to spoilage of tiger nut drink, also the reseach acknowledge the more scientific research to investigate on other microoganism apart from fungal species that can leads to tiger nut spoilage.

Keywords; Fungal,Isolation, identification and Tiger nut

GREEN SYNTHESIS OF ZINC-OXIDE NANOPARTICLES USING *Achyranthes aspera* LEAF EXTRACT AND THEIR POTENT ACTION AGAINST THE POULTRY PATHOGENS

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ABSTRACT

Nanotechnology is an emerging field worldwide because of its tremendous properties linked to the high surface area to volume ratio, improved pharmacokinetic profile, and targeted drug delivery. In the current study, zinc oxide nanoparticles (ZnO NPs) were synthesized from *Achyranthes aspera* leaf extract, characterized by UV/Visible spectroscopy, XRD, SEM, FTIR, AFM and evaluated for antibacterial efficacy against poultry pathogenic bacterial strains. UV-visible absorption peak was found at 370 nm. XRD showed hexagonal wurtzite structure of ZnONPs while SEM results indicated an average size less than 100 nm with a minimum and maximum size of 28.63 and 61.42 nm, respectively. Further analysis of synthesized nanoparticles by FTIR showed stretching frequency at 3393.14 cm^{-1}, 2830.99 cm^{-1}, 2285.23 cm^{-1}, and 2108.78 cm^{-1}. The antibacterial activity of newly developed nanoparticles was investigated against common poultry pathogens *Salmonella gallinarum* and *Salmonella enteritidis* by the disk diffusion method. It showed zones of inhibition with a diameter of 27.6 and 28.8 mm. The minimum inhibitory concentration was 0.39 and 0.195 mg/mL, respectively, which was quite interesting compared to extract zero activity at this concentration. Characterization with different techniques showed a uniform and stable synthesis of ZnO NPs. Furthermore, the findings confirm the higher activity of nanoconjugate in comparison to leaf extract and pure drug against pathogenic bacteria.

Keywords: poultry pathogens, green synthesis, *Achyranthes aspera*, surface characterization, zinc oxide nanoparticles

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PHYTOCHEMICAL SCREENING AND ANTIMICROBIAL ACTIVITIES OF LEAVES EXTRACT OF **Dodonaea viscosa* Linn.

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ABSTRACT

The increasing prevalence of antibiotic resistance necessitates the exploration of alternative antimicrobial agents, particularly from medicinal plants. This study investigated the phytochemical composition and antimicrobial efficacy of *Dodonaea viscosa* Linn. leaf extracts against pathogenic microorganisms, including *Salmonella typhi*, *Bacillus subtilis*, and *Candida albicans*. The leaves were extracted using ethanol, n-hexane, ethyl acetate, methanol, and aqueous solvents, with ethanol yielding the highest extract quantity. Phytochemical screening revealed the presence of flavonoids, saponins, tannins, terpenoids, phenols, and steroids, while alkaloids were absent. Antimicrobial activity was assessed using the agar well diffusion method, with results demonstrating concentration-dependent inhibition zones. Ethanol extracts exhibited the highest inhibitory activity, particularly against *Salmonella typhi* (20 mm zone at 100% concentration), followed by *Bacillus subtilis* and *Candida albicans*. The findings suggest that *Dodonaea viscosa* Linn. possesses significant antimicrobial properties, potentially due to its rich phytochemical profile. This study underscores the plant's potential as a source of novel antimicrobial agents and highlights the need for further research to isolate and characterize its active compounds.

Keywords: Dodonaea viscosa*, antimicrobial activity, phytochemicals, solvent extraction, medicinal plants.

THE VALORIZATION OF *Coriandrum sativum*

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ABSTRACT

Coriandrum sativum, commonly known as coriander, is an aromatic plant with multiple uses in both cooking and traditional medicine. Its valorization is based on its extracts, which contain various bioactive compounds offering health benefits and applications in the agri-food sector. Coriander seeds are widely used to add flavor to various dishes in different cuisines around the world. It is a key ingredient in curries, salads, and other culinary preparations.

Coriander extracts are rich in polyphenols and flavonoids, which are responsible for many therapeutic properties. These compounds are recognized for their antioxidant and antimicrobial effects. Studies have shown that coriander extracts possess significant antimicrobial effects against various pathogens, making it useful in combating foodborne infections. This property can serve as a natural additive in food products to improve their microbiological quality while meeting the growing demand for alternatives to synthetic preservatives.

Coriander also plays an important role in sustainable agriculture. Due to its insecticidal properties, coriander extracts can be integrated into integrated pest management programs against crop pests such as Tribolium castaneum, a harmful insect to stored goods. Furthermore, coriander cultivation requires fewer chemical inputs compared to other crops, making it a more sustainable option for farmers. By incorporating it into diversified agricultural systems, biodiversity can be promoted, and the resilience of agricultural ecosystems can be enhanced.

The valorization of Coriandrum sativum can contribute to the local economy by increasing farmers' incomes and creating opportunities in the agri-food industry. International markets for spices and aromatic herbs continue to grow, offering export opportunities for coriander.

In conclusion, the valorization of coriander extends well beyond its culinary use. Its antimicrobial and antioxidant properties, along with its applications in sustainable agriculture, make it a valuable plant both economically and for public health. By integrating these aspects into agricultural and industrial practices, it is possible to optimize its use while contributing to sustainable development.

Keywords: Coriander, Antimicrobial, Antioxidant, Sustainable Agriculture, Culinary Applications

UPCYCLING GRAPEFRUIT PEEL WASTE FOR MUFFIN FORTIFICATION: CHARACTERIZATION OF PHYSICAL, BIOACTIVE, AND MICROSTRUCTURAL PROPERTIES

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ABSTRACT

Upcycling food processing byproducts is a growing trend. Utilizing grapefruit (Citrus x paradisi) peel powder to formulate muffins offers an opportunity to improve nutritional and bioactive composition; however, it also demands evaluation of other food properties. Grapefruit peels (GP) were lyophilized at − 70 °C and 0.0500 mbar using a CHRIST-Alpha 2–4 LSC-basic lyophilizer and then vacuum-stored in polyethylene bags after grinding. GP powder was used at 3-12% concentration levels for the muffin fortification by replacing the base flour. Tested for antioxidant and bioactive potential, results divulged increased DPPH, FRAP, TPC, and TFC values with an increase in GP level. GP incorporation also affected the physical attributes of the developed muffins, and results indicated a decrease in muffin height but an increase in weight. Microstructural evaluation through scanning electron microscopy revealed a complex microstructure with higher porosity, irregularity at surfaces, and escalated moisture retention, causing muffins to harden and chewiness, but the compromised springiness, as scrutinized through texture profile analysis. Appearance is an important aspect to consider, as it affects the consumer appeal. Since peel powder itself is dark in color, it induced darkness to muffins, causing a decrease in lightness, i.e., L*, but an increment in a* and b* values was recorded for the developed muffins. Talking about sensory cues, panelists preferred 9% incorporation appealing for color and texture; however, due to the inherent bitterness in peel powder, a 6% incorporation level was recommended considering the taste aspect, henceforth 6% emerged finest considering the overall acceptability. Thus, grapefruit peel flour has great potential to be used for muffin enrichment with enhanced nutritional and quality attributes, illustrating an economic and eco-friendly way to create value-added products with multiple nutritional benefits.

Keywords: Grapefruit peel powder; muffin; antioxidant activity; texture; sensory studies

REPURPOSING N-ACETYLCYSTEINE: UNVEILING ITS POTENTIAL FOR MEMORY ENHANCEMENT IN ANIMAL MODEL

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ABSTRACT

N-acetylcysteine (NAC) is a well-known antioxidant and mucolytic agent with emerging evidence suggesting its neuroprotective properties. This study investigates the potential of NAC to enhance memory in an animal model, exploring its repurposing for cognitive enhancement. Adult male Albino Wistar rats weighing 200±20g were orally administered NAC at the dose of 25, 50 and 100mg/kg. On day 0, rats underwent training in the Morris Water Maze (MWM) and familiarization in the Novel Object Recognition (NOR) test. Following administration of water or respective NAC doses, memory performance was assessed using the MWM test, measuring acquisition, retention and consolidation. The NOR test was also conducted to evaluate recognition memory. Additional behavioral assessments included the open field, Skinner's box, light-dark activity box, elevated plus maze, and forced swim test were also performed. Rats were then decapitated; brain samples were isolated and stored at -70°C

to analysis by HPLC-EC. Results: NAC administration showed a dose-dependent improvement in memory performance in both the MWM and NOR tests. Behavioral activities indicate enhanced cognitive function and reduced anxiety-like behaviors post-NAC administration. Neurochemical analysis of brain samples revealed changes in dopamine and serotonin metabolism. Conclusion: NAC demonstrates capacity for memory enhancement and cognitive improvement, with effects measured via several behavioral assessments. Findings may help in extending therapeutics in cognitive disorders.

Keywords: N-acetylcysteine, Memory Enhancement, Neuroprotection, Oxidative Stress, Cognitive Function, Animal Model

INTEGRATING AI TOOLS INTO HIGHER EDUCATION CURRICULA: A MULTIDISCIPLINARY APPROACH

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ABSTRACT

As Artificial Intelligence (AI) continues to transform educational landscapes, there is a growing imperative to understand how AI tools can be effectively integrated into higher education curricula through a multidisciplinary lens. This study presents a systematic review of peer-reviewed literature published between 2021 and 2025, focusing on the application of AI tools, such as intelligent tutoring systems, generative AI, predictive analytics, and adaptive learning platforms, across diverse academic disciplines. Using the PRISMA framework, a total of 67 studies were selected from databases including Scopus, Web of Science, and IEEE Xplore. The review reveals that while STEM fields lead in practical AI adoption, emerging humanities, business, and education efforts highlight increasing interest in interdisciplinary approaches. Key themes identified include pedagogical transformation, faculty readiness, ethical considerations, and student engagement with AI. The results underscore the importance of cross-sector collaboration, institutional policy alignment, and digital and ethical AI literacy development. Furthermore, the study identifies gaps in empirical evidence regarding long-term learning outcomes and the inclusion of underrepresented disciplines. The discussion advocates for intentional curriculum design that aligns AI integration with broader educational goals, ensuring equitable access and critical engagement with AI tools. This review contributes a structured knowledge base to guide educators, policymakers, and curriculum developers in embedding AI meaningfully and ethically into higher education across all fields of study.

Keywords: Artificial Intelligence in Education, Higher Education Curriculum, Systematic Review, Multidisciplinary Integration

RESEARCH OF FASHION TRENDS IN WEDDING FASHION

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ABSTRACT

Strict limits and rules have lost their relevance. Today, women do not hesitate to combine elements of clothing from different eras and trends, creating unexpected combinations.

Every woman preparing for a wedding strives to look perfect. Therefore, choosing a wedding outfit is an important and exciting event.

The trends of 2025 surprise with their originality and unusual details: feathers, fringes, rhinestones and embroidery. Brides can now safely choose short dresses for their second outing. Long models remain classics, from minimalistic to romantic.

Mini dresses are no longer just for parties. Modern brides can choose a stylish mini wedding dress, whether it's a modest Chanel-style tweed model, an elegant bustier or a luxurious fringed dress.

Long wedding dresses are timeless classics. They can be made in a minimalist, romantic or boho style. Special attention should be paid to elegant floor-length dresses. If you like retro, take a closer look. for models with lantern sleeves and fringes.

Corset dresses are another popular silhouette–shaping trend. Simple models easily fit into a casual style, and dresses with a plunging neckline are suitable for bold brides.

An off-the-shoulder wedding dress always looks elegant. Sometimes the back can also be open. Large earrings and a high ponytail will help complement the look.

Minimalist wedding dresses are versatile and easily fit into a casual style. It can be a loose satin dress or a combination.

The tradition of white dresses is a thing of the past. Saturated colors and pastel shades are in fashion. Brides choosing alternative outfits emphasize their uniqueness.

In conclusion, modern wedding fashion is multifaceted and has no limitations. Every bride creates her own unique dream image. This is an important choice, because a wedding is a special event, and every girl wants to be irresistible.

Keywords: weddıng clothes, fashıon trends, dress, wedding fashion

SCIENTIST'S INTELLECTUAL ASSISTANT: THE ROLE OF CHATGPT IN INNOVATION

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ABSTRACT

In recent years, artificial intelligence (AI) has ceased to be an element of science fiction and has become an integral part of the modern scientific process. One of the most striking examples of AI is the use of neural networks - in particular, the ChatGPT model developed by Openai.

One of the key methods of using Chatgpt in science is the automation of routine intellectual tasks. The model performs many tasks. It generates and edits texts of scientific articles, helping in the formulation of annotations, hypotheses, literature reviews, analyzes large data arrays, extracting key ideas from scientific publications and structuring information. Translates and adapts content into different languages, contributing to international cooperation. Offers hypotheses, interprets the results of experiments and even helps in the development of research methodologies. Although the model does not replace a scientific examination, it becomes an intellectual assistant that can significantly reduce time for the preparatory stage of the study.

The use of ChatGPT in scientific and innovative activities is accompanied by a number of restrictions. One of which is the lack of primary thinking: the model does not generate truly new ideas, but only combines existing knowledge. Also, the conclusions obtained from the neural network require mandatory verification by a person-expert. It is important to maintain transparency in the use of AI and not to replace genuine author's work by generating texts.The scientific community is already conducting an active discussion about the standards and rules of the use of neural networks, including a mandatory indication of their participation in the creation of publications. Every year, the border between human intelligence and machine algorithms is becoming more and more blurry. ChatGPT and other AI systems do not replace the scientist, but enhance its capabilities. In the future, one can expect the appearance of hybrid research teams, where AI will be a full -fledged participant in the scientific process - from setting tasks to analysis and distribution of results.

Keywords: artificial intelligence, ChatGPT, science

EFFECT OF DIETARY HABITS ON COGNITIVE PERFORMANCE IN PRIMARY SCHOOL STUDENTS: A CROSS-SECTIONAL STUDY IN KHEMISSAT REGION IN MOROCCO

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ABSTRACT

Background: Among children, cognitive performance is influenced by dietary habits, health status, and socioeconomic factors. Poor diets, especially high intakes of ultra-processed foods, together with psychological stress and learning difficulties, can impair attention and concentration in school-age children. Understanding the interactions between these variables is essential for promoting better educational outcomes and long-term health.

Methods: A cross-sectional survey was conducted among primary school students in the region of Khemisset, Morocco. Socio-economic parameters, dietary habits, health status, visual problems, psychological stress and learning difficulties were assessed by questionnaires completed with parental consent. Cognitive performance was assessed using the d2R test, which measures processing speed, concentration and accuracy.

Results: Of the 330 students (53.9% girls, 46.1% boys), the majority had a BMI of less than 18.5 (59.7%). Most reported no health problems (91.2%) or vision problems (89.4%), while 32.7% experienced psychological stress and 43% had learning difficulties. Dietary habits showed that 66.9% ate three or more meals a day, but 60% skipped breakfast. The d2R test results showed that higher meal regularity and breakfast consumption were associated with better processing speed, concentration and accuracy.

Conclusion: This study highlights the significant influence of dietary habits and lifestyle factors on cognitive performance among primary school students. Regular meal consumption, particularly breakfast, was positively associated with enhanced attention, concentration, and processing accuracy. In contrast, high intake of ultra-processed foods and the presence of psychological stress and learning difficulties were linked to poorer cognitive outcomes. These findings reinforce the importance of promoting balanced nutrition and healthy routines early in life to support optimal cognitive development

Keywords: Cognitive performance, Dietary habits, Survey, Morocco.

HINDRANCES TO COMMERCIAL BANKS INVOLVEMENT IN REAL ESTATE DEVELOPMENT MINNA, NIGERIA

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ABSTRACT

The study examines hindrances to commercial banks involvement in real estate development in Minna, Nigeria. The study focuses on banks that are most reliable for financing real estate development in Nigeria namely; Fidelity Bank Plc, United Bank of Africa (UBA), Guarantee Trust Bank (GTB), and Union Bank of Nigeria (UBN). Data were collected from the head of units who are top officers from the selected banks in the study area. Information were gotten on financial products offer by commercial banks for real estate financing and challenges hindering their effectiveness. Data were analyzed using frequency distribution tables and relative importance index. The study shows that the selected commercial banks offer a range of financing products specifically for real estate development. Mortgage loan, bridge loan, and construction loan are the most effective products used by the commercial banks in facilitating real estate financing. The study further revealed that economic uncertainty ranked first with RII of 0.79, regulatory constraint is also seen as one of the challenges facing commercial banks which ranked second with RII of 0.66. High risks of default with RII of 0.60 as well as borrower creditworthiness having RII of 0.56 which ranked 4th and 5th respectively are also among the challenges associated with financing real estate development. Market volatility and limited capital available were ranked 5th and 6th with RII of 0.55 and 0.48 respectively. Addressing these challenges is crucial for enhancing the capacity of commercial banks to support real estate development and, by extension, contribute to the economic development of Nigeria. The study suggests that commercial banks should adopt innovative financing models such as Public-Private Partnerships (PPPs) and Real Estate Investment Trusts (REITs) to spread risks and increase the flow of funds into the real estate sector.

Keywords: Commercial banks, Real Estate, Development, Financing, Minna

CREATIVE TOUR PLANNING

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ABSTRACT

The purpose of this article is to examine and analyze creative tourism itineraries and the process of planning creative tours. It outlines the key stages involved in developing creative tours, with a focus on their role in supporting the growth of creative tourism. To contextualize the concept, the article provides an overview of the general definition and types of tours, their significance, the planning process, and the evolution of tour demand alongside relevant marketing strategies. It also discusses essential components to consider when designing package tours and addresses broader issues related to tour planning. Drawing on these foundations, the article explores the design and structuring of creative tour programs. Creative tourism is positioned as a sustainable model that enhances the quality of tourism activities and contributes to regional economic development. Within this framework, the development of creative tourism routes and strategic tour planning are presented as critical components.

Keywords: tour planning, individual and package tours, creative tourism, gastronomy city – Lankaran.

CREATIVE TOUR PLANNING

ÖZET

Bu makalenin amacı yaratıcı turizm ve yaratıcı tur planlamasının kurallarını açıklamak ve tartışmaktır. Yaratıcı turlar öngörülmekte ve yaratıcı turizmi geliştirmek amacıyla tarihleri not edilmektedir. Yaratıcı tur kavramını anlamak için makalede turun genel tanımı ve türleri, önemi, planlama süreci, turlara olan talebin gelişimi ve pazarlama rotaları hakkında kısa bir açıklama sunulmaktadır. Paket tur hazırlanırken dikkat edilmesi gereken temel unsurlar dikkate alınarak tur planlaması ve turlarla ilgili genel konular hakkında bilgi verilmektedir. Bunlara dayanarak yaratıcı turların tasarımı tartışılmaktadır. Bölgesel ekonomik kalkınmayı sağlamak için turizm bölgelerinde kaliteli turizm faaliyetlerinin sürdürülebilirliği temelinde yaratıcı turizm geliştirilmektedir. Bu bağlamda yaratıcı turizm rehberlerinin ve yaratıcı tur planlarının hazırlanması büyük önem taşımaktadır.

Anahtar Kelimeler: tur planlama, bireysel ve paket turlar, yaratıcı turizm, gastronomi şehri – Lenkeran.

FINANCIAL SYSTEM STRUCTURE AND BUSINESS FINANCING IN MOROCCO

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ABSTRACT

This study examines how the structure of Morocco's financial system affects corporate financing methods. In a banking-dominated context, companies—especially SMEs—rely heavily on bank loans, with limited access to capital markets. The underdevelopment of the stock market, the lack of diversified financial instruments, and conservative lending practices hinder access to appropriate funding for business growth. Ongoing reforms aim to improve the situation by promoting participatory finance, private equity, and public support mechanisms. A more diversified financial system is crucial to better meet the needs of the national entrepreneurial landscape.

Keywords : Financial system, Business, companies

MODELING AND MULTI-OBJECTIVE OPTIMIZATION OF SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE IN PEEK CF30% TURNING USING RSM AND DESIRABILITY FUNCTION

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ABSTRACT

Carbon fiber reinforced polymers such as PEEK CF30% are widely used in aerospace and biomedical sectors due to their high strength and thermal resistance. These polymers exhibit various machining challenges mainly represented by irregular surface finish and low productivity. It is therefore crucial to optimize the cutting conditions in order to address these two issues. In the present study that involves the turning of PEEK CF30% using PCD tools, both productivity and surface quality were assessed. To this end, an experimental plan based on the Taguchi L_{18} design was applied in order to structure the experiments. The influence of the cutting parameters represented by the cutting speed (*Vc*), the feed rate (*f*), the depth of cut (*ap*) and the tool nose radius (*r*) on the surface roughness (*Ra*) and material removal rate (MRR) was investigated. A statistical approach based on the Analysis of Variance (ANOVA) procedure was employed to identify the most significant factors affecting (*Ra*). It was found that the feed rate (*f*) had the highest impact on (*Ra*). Moreover, the Response Surface Methodology (RSM) method was utilized for the modelling of (*Ra*) as a function of the input parameters (*Vc*, *f*, *ap*, and *r*). Finally, multi-objective optimization was performed using the Desirability Function (*DF*) approach to identify the optimal cutting conditions that simultaneously minimize (*Ra*) and maximize (*MRR*). The results obtained led to a selection of the parameters that would lead to a high surface quality and efficient turning of PEEK CF30%, supporting improved machining strategies in industrial applications.

Keywords: PEEK CF30%, RSM, Turning, multi-objective optimization, Taguchi, Machining.

FEATURE EXTRACTION AND ANALYSIS TECHNIQUES FOR HUMAN MOTION UNDERSTANDING IN IMAGES AND VIDEOS

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ABSTRACT

The analysis of human motion from images and videos has emerged as a crucial area of research, with applications spanning biomechanics, surveillance, human-computer interaction, and sports science. This paper focuses on the extraction and analysis of relevant features to interpret and quantify human motion. By leveraging state-of-the-art techniques in computer vision, such as deep learning-based pose estimation, spatiotemporal feature extraction, and optical flow analysis, we aim to establish robust methodologies for motion analysis. Our approach integrates key feature detection and motion trajectory modeling to enhance accuracy and efficiency in recognizing complex human activities. Experimental results demonstrate the effectiveness of the proposed methods in real-world scenarios, paving the way for advancements in motion analysis technologies and their practical applications in diverse fields.

Keywords : Human Motion Analysis, Feature Extraction, Pose Estimation, Computer Vision, Video Analysis.

USING SYNTHETIC ZEOLITE Y FROM NATURAL CLAY TO IMPROVE CARBON DIOXIDE ADSORPTION USING ION EXCHANGE

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ABSTRACT

ordered microporous Y zeolite was synthesized through hydrothermal treatment using Algerian metakaolin and Ludox (40% SiO2) as the aluminum and silica sources, respectively. The metakaolin was derived from thermal activation of na tural kaolin. The resulting Y zeolite was ion-exchanged with various cations, including Cu^{2+}, Ni^{2+}, Ca^{2+}, and Na^{+}, to investigate their impact on CO2 adsorption at 0 °C. The materials were thoroughly characterized using advanced techniques such as X-ray diffraction (XRD), nitrogen adsorption at 77 K, Fouriertransform infrared spectroscopy (FTIR),and scanning electron microscopy (SEM). CO2 adsorption isotherms at 0°C were obtained using a volumetric method, revealing nonlinear concave curves indicative of strong adsorption interactions. Notably, Na-exchanged Y zeolite (Na-Y) exhibited the highest CO2 adsorption capacity, with an equilibrium capacity trend of Cu^{2+} < Ni^{2+} < Ca^{2+} < Na^{+}. The experimental adsorption data were best fitted to the Langmuir isotherm model, yielding a maximum CO2 uptake of 77.57 $cm^3 \cdot g^{-1}$ STP for Na-Y zeolite. These results highlight the potential of ion-exchanged zeolites for enhanced CO2 capture applications.

Keywords: Zeolite Na-Y, Ion exchange, Isotherm models, Langmuir isotherm. Kaolin ,CO2 adsorption

PHENYLAZONAPHTHALENE-BASED AZO DYES ARE MODIFIED CHEMICALLY TO ENHANCE THEIR PHOTOVOLTAIC QUALITIES FOR USE in DSSCs. DFT AND TD-DFT ANALYSIS

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ABSTRACT

Dye-sensitised solar cells (DSSCs) are of significant interest to researchers in the field of solar cell research due to their affordability and enhanced energy efficiency. In this study a theoretical analysis was performed on five phenylazonaphthalene-based azo dyes, utilising quantum methods, including density functional theory (DFT/B3LYP/SDD/6-311+G(d,p)) and its time-dependent derivative (TD-DFT/CAM-B3LYP/SDD/6-31+G(d,p)). The structural, electronic and optical properties of the dyes under study (C_1, C_2, C_3, C_4 and C_5) were examined and discussed, including FMO energy gap (E_g), chemical hardness (η), electronegativity (χ), chemical potential (μ), open circuit voltage (V_{oc}), softness (S), molecular electrostatic potential (MEP), light harvesting efficiency (LHE), injection driving force ΔG_{inject}, NBO analysis and maximum electronic absorption (λ_{max}). The following properties were calculated in order to evaluate their potential applications in dye-sensitised solar cells (DSSCs).

Keywords: Azo-dye; Phenylazonaphthalene; DSSCs; optoelectronic properties; DFT and TD-DFT.

SYNTHESIS OF NEW DECAVANADATE MATERIAL $Na_2[H_4V_{10}O_{28}]14H_2O$: CHARACTERIZATION AND BIOLOGICAL ACTIVITY

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ABSTRACT

A new decavanadate has been prepared by slow evaporation at room temperature. The molecular structure was investigated by single-crystal X-ray diffraction. Decavanadate compound crystallizes in triclinic system, space group P-1 (No. 2). The crystal structure of the decavanadate can be described by the decavanadate groups, the dimers $Na_2(H_2O)_{10}^{2+}$ and water molecules which are stack in layers parallel to the (010) plane. The crystal structure of the title compound is stabilized by hydrogen bonds and van der Waals interactions. The cohesion of the structure is ensured by O-H. . .O and N-H. . .O hydrogen bonds. The compound was tested against gram-negative bacteria pseudomonas aeruginosa. After 24 hours of incubation, the results show that the decavanadate compound was effective hours and he had a recovery after 24 h.

Keywords: Decavanadate, structure, Synthesis, biological activity.

CRANK-NICOLSON METHOD FOR SINGULARLY PERTURBED UNSTEADY PARABOLIC PROBLEM WITH MULTIPLE BOUNDARY TURNING POINTS

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ABSTRACT

In this paper, a numerical scheme for a time-dependent singularly perturbed parabolic convection-diffusion problem with boundary turning points is presented. The problem exhibits a left boundary layer in the spatial domain. We use the Crank-Nicolson method for temporal discretization and a non-standard finite difference approach for spatial discretization on uniform meshes. Through rigorous error analysis, it has been shown that the scheme is stable and parameter uniform convergence with second-order accuracy in time and first- order in space. Three model examples are provided to show the applicability of the scheme. It is shown that, the numerical results are in agreement with the theoretical findings.

Keywords: *Nonstandard finite difference, Singularly perturbed, Boundary turning point, Boundary layer.*

INVESTIGATING THE POTENTIAL OF FOOD WASTE AS AN INTERESTING SOURCE OF GREEN SCALE INHIBITORS

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ABSTRACT

The scale build-up phenomenon is generally defined as the accumulation of poorly soluble mineral deposits on water-contact surfaces, which frequently causes both technical and environmental problems, in addition to significant economic damage. One of the best techniques for preventing these undesired problems is the use of chemical inhibitors. Nevertheless, the use of environment-unfriendly chemicals can prove hazardous. Recently, food waste has attracted the interest of many researchers in the field of the circular economy. In this context, the aim of this study is to evaluate the scaling inhibiting potential of extracts obtained from a food waste product. This study was carried out using the non-electrochemical method LCGE under the following conditions: a temperature of 25°C, a water hardness of 40° F, degassing by atmospheric air, duration 2 hours. Results showed that the formation of scale was completely inhibited by the addition of a small quantity of the inhibitor to the water studied. In addition, the morphology and phase structure of the scale formed in the presence of the inhibitor were significantly modified. Consequently, we recommend the use of food waste extract as a new, environmentally friendly anti-scale compound.

Keywords: *Food waste, scale, circular economy, green inhibitor*

SUSTAINABLE RURAL DEVELOPMENT THROUGH ADVANCED AGRICULTURAL PRACTICES AND FOOD SECURITY IN THE WESTERN BALKANS

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ABSTRACT

Sustainable rural development remains one of the key challenges for the Western Balkan countries, particularly in the agriculture and food security sectors. This paper aims to analyze the impact of advanced agrotechnical practices and technological innovations in improving agricultural productivity, preserving food quality, and ensuring a secure supply chain in the region. Based on a comparative analysis methodology and secondary data sources from international organizations and local institutes, major challenges such as land fragmentation, lack of modern mechanization, and inadequate natural resource management have been identified. Special focus is given to the role of agricultural policies and subsidies in promoting sustainable practices, as well as the impact of vocational education in raising awareness about food safety. Findings suggest that the integration of smart technologies, such as moisture sensors and precision irrigation systems, significantly contributes to production efficiency and environmental preservation. In conclusion, the paper provides concrete recommendations for policymakers and local farmers toward building a sustainable, competitive, and EU-compliant agricultural model.

Keywords: *rural development, sustainable agriculture, food security, agricultural technology, Western Balkans*

NANOBIOTECHNOLOGY: TRANSFORMING FOOD SAFETY AND MICROBIAL DIAGNOSTICS THROUGH NANOSCALE INNOVATION

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ABSTRACT

Nanobiotechnology, an interdisciplinary field merging nanotechnology and biotechnology, is redefining the landscape of food, agriculture, and medical microbiology by harnessing the unique properties of nanoscale materials to address complex biological challenges. This study explores the evolution and application of nanobiotechnology, highlighting how its integration into food and agricultural systems enables the development of advanced diagnostic tools, targeted therapeutics, and innovative delivery mechanisms. Tracing the historical trajectory from early microbiological discoveries-such as the invention of the microscope and the establishment of germ theory-to the modern era where nanoscale interventions are commonplace, it is evident that the synergy between nanotechnology and biology has unlocked new possibilities for precision and specificity in addressing microbial threats. Recent literature and case studies reveal that nanoscale biosensors and imaging agents, such as quantum dots and magnetic nanoparticles, have significantly improved the sensitivity, speed, and accuracy of pathogen detection, facilitating early diagnosis and timely intervention in both food safety and crop protection. Nanoparticle-based delivery systems are enhancing the precision of agrochemical and therapeutic applications, reducing environmental impact, and improving crop yield and quality. Furthermore, bio-inspired nanomaterials are being utilized for soil health monitoring and smart packaging, expanding the potential of nanobiotechnology to promote sustainable agricultural practices. While these advancements offer clear advantages over traditional methods-including higher specificity, reduced side effects, and rapid response-there remain challenges related to scalability, regulatory oversight, and environmental safety. In conclusion, nanobiotechnology stands as a transformative force in food and agriculture, offering innovative solutions for diagnostics, therapeutics, and sustainability that can enhance global food security and public health. It is recommended that future efforts prioritize interdisciplinary research, robust regulatory frameworks, and the promotion of public-private partnerships to facilitate the safe and effective adoption of nanobiotechnological innovations in real-world agricultural and food systems.

MANAGERIAL INSIGHTS INTO CIRCULAR ECONOMY STRATEGIES IN THE FOOD INDUSTRY

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ABSTRACT

The transition toward sustainable practices in the food industry is increasingly being shaped by the principles of the circular economy (CE), which emphasize resource efficiency, waste minimization, and value retention across the production-consumption cycle. This study explores the managerial insights and strategic approaches adopted by food industry stakeholders to integrate circular economy principles into their business models and operations. Drawing on qualitative interviews and secondary case analyses of food processing firms, agribusinesses, and food retail enterprises, the research identifies key drivers, enablers, and barriers influencing circular strategies such as food waste valorisation, by-product reuse, sustainable packaging, and closed-loop supply chains. The findings reveal that managerial leadership, innovation culture, stakeholder collaboration, and regulatory support are critical to the successful adoption of CE practices. Moreover, the study highlights how digital technologies such as IoT, blockchain, and data analytics are enabling transparency and efficiency in circular supply chains.

The paper contributes to both academic and practical understanding by offering a strategic framework for managers to evaluate and implement circular initiatives, balancing economic performance with environmental and social goals. The insights also suggest that small and medium enterprises (SMEs) in the food sector can achieve competitive advantage through adaptive and scalable CE practices, especially when supported by ecosystem partnerships. This research underscores the pivotal role of managerial decision-making in steering the food industry toward a more regenerative, resilient, and sustainable future.

Keywords: Circular economy; Food industry; Sustainable supply chain management; Managerial strategies; Waste management; Resource efficiency.

ECONOMIC ANALYSIS OF SUGARCANE PRODUCTION IN NUMAN LOCAL GOVERNMENT, ADAMAWA STATE-NIGERIA

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ABSTRACT

This study provides a comprehensive economic analysis of sugarcane production in the Numan Local Government Area of Adamawa State, Nigeria. It examines the current state of sugarcane farming, including production practices, input costs, and yield outcomes. The study adopt the Multi-stage sampling procedure in selecting 120 registered sugarcane farmers in the study area. Data were collected through the administration of a structured questionnaire to the farmers. The study retrieved only 83 questionnaires and analyzed using simple descriptive statistics, and logistics regression analysis. The study explores the socio-economic implications for local farmers and the potential for sugarcane as a viable cash crop to enhance economic development in the region. The results indicates that, majority of the farmers are between 35-40 of age and are married. The results also revealed that majority of the sugarcane farmers in the area are secondary school graduate with an average farming experience of 11 years. The logistic regression result shows that all the variables included in the model are jointly significant in predicting the factors influencing sugarcane production in the study area. Based on the findings, the study recommends that both the government and the private sectors should provide access to resources, infrastructural facilities, address environmental factors, and also identifying opportunities for improving production efficiency and profitability. These will support sustainable sugarcane farming and contribute to the agricultural development of Adamawa State.

Keywords: Sugarcane, Farming, Production, Economic Analysis

GRENADINE MOLASSES: BETWEEN PROMISES AND CHALLENGES

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ABSTRACT

Pomegranate syrup, or pomegranate molasses, is a traditional product rich in bioactive compounds such as polyphenols (punicalagin, ellagic acid), flavonoids, and anthocyanins, recognized for their antioxidant, anti-inflammatory, and cardiovascular protective effects. While scientific research has confirmed, through clinical trials, the benefits of pomegranate juice or extracts on memory, heart health, metabolism, and immunity, few studies have yet specifically targeted artisanal molasses. However, the prolonged cooking used in its production can alter certain sensitive molecules, while preserving or activating other, more stable compounds. Promoting local pomegranate varieties, adapted to Mediterranean terroirs and rich in tannins, offers promising potential for combining ancestral knowledge, sustainable production, and innovation in preventive health, from an epistemological perspective linking tradition and science.

Keywords: *Punica granatum* L., grenadine molasses, natraceutical, local cultivar, tannins, arid region,

MODELING OF SEMICONDUCTING POLYMER–GAS INTERACTIONS USING DFT: THE CASE OF 2-PANI"

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ABSTRACT

In this study, the interaction between the conductive polymer polyaniline (PANI) and the highly toxic hydrogen cyanide (HCN) gas was theoretically investigated. The efficiency of gas sensors greatly depends on the chemical stability, selectivity, and electrical conductivity of the sensing material. Therefore, the behavior of PANI toward HCN gas was explored in detail using quantum chemical methods. All calculations were performed using Density Functional Theory (DFT) with the B3LYP functional and the 6-311++G(d,p) basis set. Initially, the geometry of the isolated PANI molecule was optimized, and then its interaction with the HCN molecule was modeled to form adsorption complexes. After structural optimization, key electronic parameters including the energies of the Highest Occupied Molecular Orbital (HOMO) and the Lowest Unoccupied Molecular Orbital (LUMO) were calculated. The change in the HOMO–LUMO energy gap before and after adsorption provided insight into the variation in electronic properties. Additionally, global reactivity descriptors such as chemical hardness, softness, electronegativity, and electrophilicity index were evaluated to further interpret the reactivity changes of the system. Adsorption energy values were calculated to assess the strength and nature of the interaction between PANI and HCN. The recovery time (time required for desorption) was also estimated to determine the reusability and responsiveness of the sensor material. The variation in electrical conductivity, as inferred from the HOMO–LUMO gap, further supported the sensing potential.

Keywords: DFT, PANI, HCN, HOMO-LUMO

INVESTIGATION OF HYDROGEN PRODUCTION FROM METHANOLYSIS OF SODIUM BOROHYDRIDE IN THE PRESENCE OF COPPER/COBALT COMPLEX-SUPPORTED CATALYSTS

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ABSTRACT

Hydrogen has recently become very important as a clean energy carrier as an alternative to the increasing use of fossil fuels. Sodium borohydride ($NaBH_4$) is one of the most effective hydrogen sources as a storage material. Various metal-containing catalysts are also used in hydrogen production by $NaBH_4$ methanolysis. In this study, the hydrogen production performances of cobalt- and copper-complex-supported catalysts on SiO_2 and Al_2O_3 were systematically investigated through the methanolysis of sodium borohydride ($NaBH_4$). Catalysts were prepared by adsorbing different amounts (1–5 mg) of metal complexes onto the support materials and tested under constant conditions (30 °C, 0.25 g $NaBH_4$, 0.1 g catalyst, and 10 mL solvent). For SiO_2-supported catalysts, the highest hydrogen generation rate (HGR) was obtained with pure SiO_2 at 3614 $mL \cdot min^{-1} \cdot g^{-1}$. Among the cobalt-complex-supported SiO_2 catalysts, the maximum HGR was 2080.3 $mL \cdot min^{-1} \cdot g^{-1}$ with 1 mg Co, although pure SiO_2 again demonstrated the highest performance in this series. For Al_2O_3-supported systems, the most efficient catalyst was found to be the one with 4 mg Co, yielding an HGR of 2446.4 $mL \cdot min^{-1} \cdot g^{-1}$. In the copper-complex-supported systems, Cu-SiO_2-4 mg showed the highest performance with an HGR of 3300 $mL \cdot min^{-1} \cdot g^{-1}$, while the Cu-$Al_2O_3$ catalyst with 1 mg Cu achieved a maximum of 1716.8 $mL \cdot min^{-1} \cdot g^{-1}$. In hydrolysis conditions, only the $CoAl_2O_3$-4 mg catalyst was able to produce hydrogen, with an HGR of 1142 $mL \cdot min^{-1} \cdot g^{-1}$. Additionally, the activation energies for the reactions were calculated. The results indicate that methanol is a more suitable medium than water for both cobalt and copper complex-supported catalysts. This study highlights the significant impact of metal complex concentration and support type on hydrogen production and provides valuable insight for future catalyst design.

Keywords: $NaBH_4$, Hydrogen, Catalyst, SiO_2, Al_2O_3.

ON THE CONFORMAL* CURVATURE TENSOR IN RIEMANNIAN SUBMERSIONS WITH QUARTER-SYMMETRIC NON-METRIC CONNECTIONS

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ABSTRACT

This study investigates the behaviour of the conformal* curvature tensor at Riemannian submersions endowed with quarter-symmetric non-metric connections. Initially, we introduce fundamental concepts related to Riemannian submersions, the conformal* curvature tensor, and quarter-symmetric non-metric connections, emphasizing their significance within the context of differential geometry and theoretical physics. The conformal* curvature tensor, an important generalization of the classical conformal curvature tensor, is examined comprehensively to explain its geometric characteristics and variations under these specialized connections.

The primary objective of this research is to derive explicit expressions for the conformal* curvature tensor in the context of Riemannian submersions endowed with quarter-symmetric non-metric connections. This investigation facilitates an enhanced understanding of geometric structures and provides a solid foundation for further theoretical developments and practical applications. Through systematic analysis, the study sheds light on how these specialized connections influence the geometric properties of submersions.

Moreover, specific attention is dedicated to examining the case where the total space of Riemannian submersions has umbilical fibers. For these particular cases, detailed results related to various curvature tensors, including the conformal* curvature tensor, are obtained and discussed thoroughly. These findings contribute significantly to the existing knowledge base, offering new insights into curvature interactions and geometric configurations. Consequently, this investigation opens avenues for potential applications in theoretical physics, manifold theory, and complex geometric modeling, enriching current geometric and physical understanding.

Keywords: Riemannian submersions, conformal* curvature tensor, quarter-symmetric non-metric connections, umbilical fibers.

DEVELOPMENT OF ILLUMINATED FEEDBACK IN HOB CONTROL

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ABSTRACT

In conventional gas hobs, the main information provided to the user about the hob status is provided by silkscreened symbols and markings on the control knobs. Although these systems basically show the user which burner is switched on and which direction the gas flow is switched to, they are limited in terms of visual feedback. It may cause user errors, especially in low-light environments or in emergency situations.

New generation hobs with light indicators offer a more advanced and dynamic information transfer to the user. LED-based indicators on each burner light up when the hob is on, alerting the user and visually indicating that the burner is active. These systems not only show the on or off status of the hobs, but also visualise functions such as the presence of gas flow, heat levels and, in some models, hazard warnings, thereby increasing user safety.

Another important advantage of this technology is that the control knob and the associated combustible eye can be illuminated in the same colour. This allows the user to easily recognise which button belongs to which burner and minimises the risk of confusion. This feature provides a significant ergonomic advantage, especially for older users or individuals with visual sensitivity.

Dynamic warning systems such as colour change and flashing provide instant and understandable information to the user. In this context, illuminated indicators; Reduces user errors by strengthening visual perception, button-eye mapping makes it easy to control, increases the level of security, provides ease of use in dark environments, it increases the perceived quality of the product with its modern design language.

As a result, the classic silkscreen-based displays are increasingly being replaced by more functional and user-friendly illuminated display systems. This transformation should be considered an important innovation not only in terms of aesthetics and technology, but also in terms of user safety, control precision and ergonomics.

Keywords: Indicator, Stove, Serigraphy, Safety, Ergonomics, LED, Control

OCAK KONTROLÜNDE IŞIKLI GERİ BİLDİRİM GELİŞTİRİLMESİ

ÖZET

Geleneksel gazlı ocaklarda kullanıcıya ocak durumu hakkında bilgi veren başlıca unsur, serigrafiyle belirtilmiş semboller ve kontrol düğmeleri üzerindeki işaretlerdir. Bu sistemler temel düzeyde kullanıcıya hangi brülörün açık olduğunu ve gaz akışının hangi yöne çevrilerek sağlandığını gösterse de, görsel geri bildirim konusunda sınırlı kalır. Özellikle düşük ışıklı ortamlarda veya acil durumlarda kullanıcı hatalarına sebebiyet verebilir.

Yeni nesil ışıklı göstergeli ocaklar ise kullanıcıya daha gelişmiş ve dinamik bir bilgi aktarımı sunmaktadır. Her brülör üzerinde yer alan LED tabanlı göstergeler, ocak açık olduğunda yanarak kullanıcıyı uyarır ve görsel olarak brülörün aktif olduğunu belirtir. Bu sistemler, yalnızca ocakların açık veya kapalı durumunu göstermekle kalmayıp, aynı zamanda gaz akışının varlığı, ısı seviyeleri ve bazı modellerde tehlike uyarıları gibi fonksiyonları da görselleştirerek kullanıcı güvenliğini artırır.

Bu teknolojinin bir diğer önemli avantajı, kontrol düğmesiyle ilişkili yanıcı gözün aynı renkte aydınlatılabilmesidir. Böylece kullanıcı, hangi düğmenin hangi brülöre ait olduğunu kolayca algılayabilir ve karışıklık riski minimuma indirilir. Bu özellik, özellikle yaşlı kullanıcılar veya görsel hassasiyeti olan bireyler için ciddi bir ergonomi avantajı sağlar.

Renk değiştirme ve yanıp sönme gibi dinamik uyarı sistemleri sayesinde kullanıcıya anlık ve anlaşılır bilgi aktarımı yapılır. Bu bağlamda, ışıklı göstergeler; görsel algıyı güçlendirerek kullanıcı hatalarını azaltır, düğme-göz eşleştirmesiyle kontrolü kolaylaştırır, güvenlik seviyesini artırır, karanlık ortamlarda kullanım kolaylığı sağlar, modern tasarım diliyle ürünün algılanan kalitesini yükseltir.

Sonuç olarak, serigrafi tabanlı klasik göstergeler yerini giderek daha fazla fonksiyonel ve kullanıcı dostu olan ışıklı gösterge sistemlerine bırakmaktadır. Bu dönüşüm, yalnızca estetik ve teknoloji anlamında değil, aynı zamanda kullanıcı güvenliği, kontrol hassasiyeti ve ergonomi açısından da önemli bir yenilik olarak değerlendirilmelidir.

Anahtar Kelimeler: Gösterge, Ocak, Serigrafi, Güvenlik, Ergonomi, LED, Kontrol

THERMAL STABILITY ANALYSIS OF HYDROPHOBIC SOL-GEL COATINGS ON GLASS SURFACES USED IN THE HOME APPLIANCE INDUSTRY AS A FUNCTION OF CURING TEMPERATURE

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ABSTRACT

In this study, hydrophobic sol-gel coatings were developed for application on glass surfaces used in the home appliance industry, with a focus on stovetop glasses that must endure high thermal resistance. Two types of formulations were prepared using the sol-gel technique: one based on polydimethylsiloxane (PDMS), a widely used silicone polymer known for its hydrophobic properties, and another referred to as FSilan, a hybrid silane system composed of tetraethyl orthosilicate (TEOS), methyltrimethoxysilane (MTMS), HCTMO (a group of organic silane derivatives such as hydrochlorothiazide or trimethylolethane/ trimethylolpropane /trimethyloxirane), and glycidyloxypropyltrimethoxysilane (GLYMO). Each coating was applied to soda-lime glass substrates and cured at different temperatures (150 °C, 200 °C, 250 °C 300 °C and 350 °C) to investigate the influence of curing conditions on surface hydrophobicity and thermal stability. Surface characterization was conducted through water contact angle measurements to assess wettability, while surface morphology and elemental composition were analyzed using SEM and EDS. Following thermal exposure, changes in hydrophobic performance and surface structure were evaluated based on post-heating contact angle measurements and SEM imaging. The findings revealed a strong correlation between curing temperature and coating performance. While both formulations showed hydrophobic characteristics post-curing, FSilan-based coatings maintained their structural integrity and water repellency at higher temperatures, outperforming PDMS-based systems in thermal durability. These results provide insights into optimizing sol-gel-derived hydrophobic coatings for functional glass surfaces in domestic appliances, contributing to the development of thermally stable, long-lasting, and efficient surface treatments in industrial applications.

Keywords: hydrophobic sol-gel coating, thermal stability, curing

THE EFFECT OF PLASMA SURFACE TREATMENT PARAMETERS AND ADHESIVE TYPE ON THE BONDING STRENGTH OF NEXT-GENERATION ALUMINUM AND COMPOSITE SHEETS

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ABSTRACT

The adhesive bonding of materials has been the focus of numerous recent studies worldwide due to its advantages, including reduced component requirements, the ability to form joints free from residual stresses, ease of application, provision of sealing and insulation, lower weight compared to bolting, nut-and-bolt assemblies, and riveting, as well as lower processing temperatures compared to welding. Furthermore, owing to these advantages, adhesive bonding is widely employed in the aerospace, aviation, automotive, and defence industries.

In this study, the effects of plasma surface treatment parameters and adhesive type on the bonding performance of aluminum and basalt fiber reinforced polyamide matrix composite (BFRP) plates were investigated. The effectiveness of plasma surface treatment varies depending on parameters such as frequency (Hz), power (W), and treatment duration (s). In this research, the frequency (1250 Hz) and power (200 W) values were kept constant, and the influence of different treatment durations (30, 60, 90, and 120 seconds) on adhesion performance was examined. Additionally, two commercial adhesives (cyanoacrylate-based Loctite 401 and epoxy-based Loctite 3430) were used as variables to evaluate the interaction of different adhesive chemistries with aluminum and composite (BFRP) materials. For each parameter set, five tensile specimens were prepared, and the shear strength of the adhesively bonded materials was measured. Specimens without any surface treatment withstood a shear force of 0.65 kN, whereas those exposed to plasma surface treatment for 60 seconds demonstrated a significantly enhanced shear strength of 3.31 kN, corresponding to an increase of approximately 409%. Fracture surface analysis was conducted to calculate the adhesive-to-cohesive failure ratio for each parameter. In the future scope of this study, FT-IR analysis, microstructural imaging via SEM, contact angle measurements, and XPS analysis will be carried out to further expand the investigation.

Keywords: Adhesive bonding, plasma treatment, aluminum, composite.

POSTHARVEST QUALITY OF 'AĞIN BEYAZI' GRAPE BY GREEN SYNTHESIS OF CALCIUM NANOPARTICLES FROM *Sideritis pisidica*

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ABSTRACT

This study aimed to investigate the synthesis, characterization, and postharvest application of calcium-based nanoparticles derived frım *Sideritis pisidica* Boiss. & Heldr. (SPNPs) for maintaining the quality of 'Ağın Beyazı' grapes over 20 days of cold storage. *S. pisidica*, a natural medicinal plant of the southwestern region of Türkiye, is rich in phytochemicals with antioxidant and antimicrobial activities and hence an ideal choice for green nanoparticle synthesis. SPNPs were prepared with the assistance of a precursor $CaCl_2$ and were characterized by UV-visible and FTIR spectroscopy to ascertain confirmation of the synthesis and stabilization of the nanoparticles because of the functionality of the plant source.

Grapes were subjected to SPNP treatment at 25, 50, and 100 mg/L levels and also compared with the control maintained at 4°C. These physicochemical parameters were measured such as firmness, respiration rate, total soluble solids (TSS), titratable acidity, pH, and color coordinates (L*, a*, b*). The outcomes showed that SPNP treatment did not significantly impact fruit firmness, pH, titratable acidity, or TSS relative to the control but significantly affected respiration rate and color retention. There was an elevated respiration rate in the later stages of storage in 100 mg/L SPNP-treated grapes. In addition, the values of b* (blue-yellow axis) showed smaller increments in SPNP-treated grapes.

The findings show that SPNPs are not highly effective as an environmentally friendly approach to extending the shelf life and quality of the grapes. While the SPNP treatments did not significantly impact compositional and structural aspects, their impact on respiration and color retention warrants further research, particularly on optimal concentration and treatment procedures.

Keywords: Green synthesis, calcium nanoparticle, grape berry coating

WILD PLANTS THAT ARE CONSUMED AS VEGETABLES IN THE PROVINCE OF BINGÖL

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ABSTRACT

Plants have been the hub of human life since the start of civilization, serving as basic sources of food, medicine, clothing, and shelter. Of their many contributions, the most critical is that they provide human nutrition. With experience spanning thousands of years, humans have acquired knowledge to consume various plant part which are fruits, leaves, seeds, roots, flowers, and tubers. Even today, especially in the countryside, wild plants are heavily harvested and eaten as part of traditional cuisine. With the rising awareness of natural nutrition and health, there is a growing popularity of herbal and wild edible plants globally.

Türkiye is one of the richest countries in terms of wild and domesticated plants due to its diverse climates, ecological zones, and its historical position as a bridge between continents and civilisations. This natural richness enables many wild edible plants to naturally grow. The province of Bingöl, located in eastern Anatolia, has a very rich vegetation that has not yet been thoroughly explored. It is essential for both the ecological balance and the cultural heritage that this natural wealth is properly conserved and utilised.

This study examines some of the wild edible plant species that occur naturally in Bingöl, including *Anchusa azurea, Urtica membranacea, Ferula meifolia, Gundelia Tourneforti, Crocus spp., Rheum ribes, Arum maculatum, Nasturtium officinale, Chenopodium album, Asparagus officinalis, Capsella rubella, Portulaca oleracea, Mentha pulegium, Allium ampeloprasum, Rumex tuberosus, Satureja hortensis, Raphanus raphanistrum, Eremurus spectabilis*. Of these species, *Eremurus spectabilis, Anchusa azurea, Urtica membranacea, Arum maculatum, Nasturtium officinale, Chenopodium album, Rumex tuberosus*, and *Portulaca oleracea* are the most widely known and consumed.

The research covers their taxonomy, lifespan, ecological requirements, edible parts, nutritional content, traditional use, as well as field activities including interviews with plant taxonomy experts from Bingöl University and residents of 12 villages.

Keywords: Wild edible plants, biodiversity, genetic resources, sustainability

THE ROLE OF PHARMACIES IN COLD CHAIN MEDICINES MANAGEMENT AND NANOTECHNOLOGICAL APPROACHES

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ABSTRACT

Today, accurate, safe and effective delivery of therapeutic drugs to patients is of great importance in the effectiveness of health services. Especially for medicines with high temperature sensitivity, such as biotechnological products, vaccines, insulins and some special formulations, this process is carried out within a special logistics system called "cold chain". The cold chain is an integrated system that ensures the transfer of medicines from the production stage to the end user, protected at specific temperature ranges, and any disruption in any link of the chain can completely eliminate the effectiveness of the medicine. The most fragile link in this chain is pharmacies, which often lack adequate technical infrastructure. This study aims to examine the challenges pharmacies face in managing medicines in the cold chain and the contribution of nanotechnology to this process. Using literature review and analysis methods for current practices, the processes of pharmacies to store, track and deliver temperature-controlled products to patients were evaluated. In addition, the effects of nanotechnological drug formulations and nano-sensor technologies on cold chain processes were discussed. Pharmacies are the last distribution point that is highly vulnerable to temperature deviations. Inadequate infrastructure, lack of calibration and uninterrupted power supplies increase the risk of cold chain breakage. Nanotechnology-based formulations (e.g. lipid nanoparticle carrier systems) have significant potential to reduce this risk. In addition, nano-sensor labeling systems provide pharmacies with a great advantage in monitoring the reliability of the product. The safe management of cold chain medicines requires not only logistics but also knowledge, infrastructure and regulatory compliance. It is of great importance that pharmacies are not left alone in this process, supported and especially integrated into nanotechnological developments.

Keywords: Pharmacy, cold chain, nanotechnology, drug safety, temperature monitoring.

OXIDATIVE STRESS IMPACT OF TOXIC HEAVY METALS ON GIANT AFRICAN LAND SNAILS (*Achatina achatina* and *Achatina fulica*)

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ABSTRACT

The bioaccumulation of heavy metals in snails has implications for ecosystem health and food web dynamics as snails serve as a pathway for transferring metals to predators, scavengers including humans that consume them. This study analysed the levels of heavy metals (Manganese (Mn), Iron (Fe), Cadmium (Cd), Arsenic (As), Lead (Pb), Chromium (Cr), Copper (Cu) and Zinc (Zn) in land snails and investigated the use of antioxidant defence system as biomarkers. Enzyme activities of Catalase (CAT), Superoxide dismutase (SOD), Glutathione-S-transferase (GST) and Malondialdehyde (MDA) were used to evaluate the oxidative stress impact of toxic heavy metals on the snails. Forty-nine matured giant land snails were purchased from OAU Incinerator and Ikire Town. The snails were analysed for bioaccumulation of heavy metals using an Atomic Absorption Spectrophotometer. The results showed that in *A. fulica* from OAU Incinerator, Cu and Cr were highest in the foot (4.011 ± 0.000) mg/Kg and (2.111 ± 0.000) mg/Kg respectively, Fe and Cd were predominant in the digestive gland (2.116 ± 0.000) mg/Kg and (1.112 ± 0.000) mg/Kg respectively whereas *A. achatina* from Ikire accumulated the highest concentration of As (1.116 ± 0.000) mg/Kg, and Zn (2.117 ± 0.000) mg/Kg in the digestive gland, while the gonad accumulated more Fe (1.903 ± 0.001) mg/Kg, Cd (2.009 ± 0.000) mg/Kg and Cr (1.503 ± 0.000) mg/Kg than other tissues. The results recorded in this study were above the permissible limit of FAO/WHO expect for Cd in *A. fulica* and Zn in *A. achatina*. The enzymatic activity of MDA, SOD and GST are higher in *A. fulica* from OAU Incinerator than in *A. achatina* in Ikire except CAT. The input of these heavy metals into the environment occurs through anthropogenic activities such as municipal wastewater, antifouling measures, indiscriminate use of manure and fertilizers, disposal of household and manufacturing industrial wastes. This study would recommend very close monitoring of agrochemical applications, proper waste disposal and other anthropogenic activity in the two sites.

OPTIMIZING PERFORMANCE AND USER EXPERIENCE IN ONLINE FOOD DELIVERY PLATFORMS USING DATABRICKS AND DELTA LAKE

S. MUNEESWARI

ABSTRACT

The exponential growth of online food delivery platforms has resulted in a surge of high-volume, diverse, and real-time data generated from user interactions, order logistics, vendor performance, and delivery tracking. **Understanding and optimizing this complex data ecosystem is critical to enhancing user experience and operational efficiency.**

This study presents a **scalable analytical framework** built on the **Databricks Unified Analytics Platform**, leveraging **Apache Spark**, **Delta Lake**, **Structured Streaming**, and **MLflow**. The aim is to enable comprehensive data-driven insights and real-time decision-making for food delivery platforms.

The proposed approach is motivated by the need for **reliable, maintainable, and real-time data pipelines** that support predictive modeling, anomaly detection, and behavioral analytics in a high-velocity data environment. The framework addresses these needs by integrating a modern data lakehouse architecture with advanced machine learning and streaming capabilities.

Methodologically, the study involves ingesting and transforming large-scale structured and semi-structured datasets—including clickstream logs, order metadata, and customer feedback—via Spark-based data pipelines. We applied **predictive analytics**, **clustering**, and **real-time anomaly detection** to uncover insights into customer engagement, order fulfillment bottlenecks, churn risk, and demand variability.

The system design includes **Delta Lake** for ACID-compliant data storage and version control, **feature engineering pipelines** for delivery delay forecasting and dynamic pricing, and **Delta Live Tables** for automated, real-time data orchestration. **Databricks Notebooks** were employed for collaborative development and experiment tracking via MLflow.

Implementation results show improved data quality, reduced delivery prediction error, and timely identification of anomalies affecting customer satisfaction and delivery logistics. The integration of real-time and historical data streams significantly enhanced model accuracy and operational responsiveness.

In conclusion, this work demonstrates the effectiveness of a unified, scalable analytics architecture in transforming raw operational data into actionable insights, thereby driving intelligent decision-making, improved user experiences, and competitive differentiation in the online food delivery sector.

Keywords: *Online Food Delivery, Databricks, Delta Lake, Structured Streaming, Predictive Analytics, Real-time Data Processing, Anomaly Detection, User Behavior Analytics*

IMPACT OF AVIAN COCCIDIOSIS ON INTESTINAL INTEGRITY : DAMAGE QUANTIFICATION THROUGH HISTOMORPHOMETRIC ANALYSIS

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ABSTRACT

Avian coccidiosis is a widespread intestinal parasitic disease that significantly affects poultry health and productivity. The infection compromises intestinal structure and function, leading to poor nutrient absorption and growth retardation. Evaluating intestinal damage is crucial for monitoring disease severity and improving management strategies. A one-year prevalence study was conducted in a poultry slaughterhouse. Intestinal samples (duodenum, jejunum, ileum, cecum) were collected and analyzed using flotation techniques to distinguish between infested and non-infested groups. Histological sections were prepared using standard protocols and examined under a light microscope (magnification ×3.2) equipped with a digital camera (Future WinJoe). Morphometric measurements of villus height (VH) and crypt depth (CD) were performed using ImageJ software (version 1.52, NIH, USA). Histomorphometric analysis revealed a significant reduction in villus height ($p < 0.001$) in infected chickens, especially in the jejunum (from 1047.94 ± 20.91 to 681.85 ± 16.50) and cecum (from 520.02 ± 14.45 to 218.54 ± 6.44). Crypt depth was significantly increased ($p < 0.05$) in the infested group. The VH/CD ratio was markedly lower in infested chickens, indicating compromised intestinal absorptive function. This study highlights the detrimental impact of coccidiosis on intestinal architecture and function. Histomorphometric analysis provides a valuable quantitative tool for assessing gut health in poultry and contributes to the development of targeted strategies for disease monitoring and control in livestock farming.

Keywords: coccidiosis, avian, villus, crypt, µm

INFLUENCE OF WATER TEMPERATURES ON THE DYNAMICS OF SPERMATOGENESIS IN WILD FLATHEAD MULLET MUGIL CEPHALUS (Linnaeus, 1758)

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ABSTRACT

In natural aquatic environments, water temperature is a critical abiotic factor influencing fish reproduction, particularly spermatogenesis. Seasonal thermal fluctuations play a pivotal role in regulating testicular development and gamete production, thereby shaping the reproductive cycle. This study investigates the influence of natural water temperature variations on the quantitative dynamics of spermatogenesis in Mugil cephalus, a species of both ecological and economic importance. Over a 9-month period, from July 2014 to December 2015, male specimens were collected from commercial catches in the Gulf of Bejaia (northeastern Algeria), under uncontrolled natural thermal conditions. To assess spermatogenic activity, two histological parameters were measured: the absolute number of seminiferous lobules (SN) per microscopic field and their surface area (SA). These metrics served as indicators of the progression and intensity of spermatogenesis. The results revealed that spermatogenesis in M. cephalus is highly sensitive to thermal variation, with significant correlations observed particularly at lower water temperatures. An inverse relationship between seminiferous lobules (SN) and surface area (SA) was consistently found, highlighting distinct phases of reproductive activity. This suggests that thermal cues play a regulatory role in testicular function and gametogenic output. These findings underscore the critical importance of understanding the interplay between environmental factors and reproductive biology in wild fish populations. Such insights can significantly contribute to the optimization of aquaculture protocols and the sustainable management of M. cephalus, especially in the context of ongoing climate variability and its potential impact on marine ecosystems.

Keywords: Mugil cephalus, surface area of seminiferous lobules, number of seminiferous lobules , Water Temperature, wild condition.

DETERMINATION OF NITRATE IONS (NO_3^-), IN RED MEAT OF ANIMALS, IN THE CITY OF PRISTINE, THROUGH THE INSTRUMENT "GREEN TEST ECO 5 F –ANMEZ"

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ABSTRACT

The advancement of meat preparing innovation in Kosovo over the final decade has essentially affected the nourishment industry, particularly in guaranteeing nourishment security and open wellbeing within the nearby advertise. This ponder analyzes the usage of meat handling strategies and compliance with guidelines set by wellbeing and nourishment security organizations in different slaughterhouses and megamarkets. We gotten Ten ruddy meat tests (new and handled) and subjected them to comprehensive research facility tests, counting physicochemical, microbiological and nitrate examinations. The comes about affirmed that all tried tests complied with national and worldwide quality benchmarks, appearing secure levels of fat, protein, salt, water and nitrate, and were free of destructive pathogens such as Salmonella, Staphylococcus aureus and E. coli. The ponder too highlights the dietary significance of proteins in meat and looks at the potential wellbeing impacts of nitrate bioaccumulation. The watched mechanical strategies - from crude fabric determination to bundling - illustrated a tall level of operational security and cleanliness. In spite of these progresses, assist change in normal usage and open mindfulness is suggested to guarantee proceeded advance in nourishment security.

Keywords: Nourishment security, Open wellbeing, Meat preparing, Nitrates in meat, Quality control, Microbiological examination, Kosovo, Nourishment innovation

CYTOKININ HORMOPRIMING AND THE GERMINATION OF SOME *Solanaceae* CROP VARIETIES FROM BULGARIA

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ABSTRACT

Although Bulgarian farmers have been cultivating the New World crops from the *Solanaceae* family for a few centuries, it took more than a century to get widespread acceptance and rise to the top of the Bulgarian population's vegetable consumption list. So it is no wonder that in the 20th century, Bulgaria became one of the world's leading producers of these crops. Due to their significance, such crops as pepper, tomatoes and etc. got in the focus of breeding initiatives aimed at enhancing local adaptability and nutritional characteristics. One of the outcomes of such endeavors were development of many local cultivars with improved adaptation to the local conditions and consumers demands. Also many of these cultivar have exceptional blend of traits as high production, high nutritional content, and distinctive fruit flavor and scent all of which garnered respect and fame to Bulgaria and Bulgarian agro-scientists and farmers and gave nutritional delight to the renownly picky local consumers.

Due to such factors these cultivars are cultivated locally in a variety of environmental settings, some of which aren't ideal for the plants. Priming with certain plant growth regulators has been shown to have beneficial impacts on plant development in both normal and stressed conditions in many plant species. Since the early stages of plant ontogenesis are among the most critical for the crop's long-term survival, growth, and yield, then research on the effects of certain cytokinin-acting plant growth regulators on the early stages of development can be beneficiary for the growers and farmers.

In this work is presented some of the research and results in this area done in Bulgaria with some of the cultivars of the New World *Solanaceae* crops.

Keywords: cytokinin, hormopriming, plant hormone, Solanaceae, *Solanum lycopersicum, Capsicum annuum*.

EFFECT OF INSURGENCY ON INCOME OF MARKETERS IN CHIKUN LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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ABSTRACT

The study analyzed the effect of insurgency on income of grain marketers in Kaduna State, Nigeria. The specific objectives were to: describe the socio-economic characteristics of the respondent in the study area; identify the type of insurgence activities; determine the effect of insurgency on income of the respondents and identify the constraint faced by marketers in the study area. A multi-stage sampling technique was employed to select one hundred thirty two (132) marketers in Chikun Local Government Area of Kaduna State due to the prevalence of insurgence activities in the area. Data were collected through structured questionnaire and were analyzed using descriptive statistics and Ordinary Least Square (OLS) regression model. The result showed that majority (85.6%) of the marketers were married with a mean age of 44 years and majority (79.5%) had secondary education as their highest level of qualification. The result shows that almost all the respondent (96.2%) have experienced insurgency activity with more than half of the respondents indicated kidnaping (59.8%) and sporadic shooting (20.5%) as the highest forms of insurgency experience in the study area. However, the OLS result shows that, age positively affected income at 10% level of probability, while household size, frequency of occurrence of insurgent activity and severity of the insurgency negatively affected the income of the marketers at 10%, 1% and 5% level of probability respectively in the study area. The most pressing constraints faced by the marketers includes; high cost of crop (X=2.41), lack of access to market (X=2.27), high cost transportation (X=2.23) and low patronage (X=2.03) ranked among the top four (4) major constraints in the study area, the study area. The study recommends improve security checks in the study area.

Keywords: *Insurgency, Income and Grain Marketers*

ENGINEERING AN AUTOMATED MODEL FOR FOOD CLASSIFICATION (CNNAFCM) BASED ON PICTURES OF NIGERIAN INDIGENOUS LUNCHES WITH THE PURPOSE OF AI IN AGRICULTURE

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ABSTRACT

As a result of this study, a powerful model called the Convolutional Neural Network-Based Automatic Food Classification Model (CNNAFCM) was created, using images of Nigerian swallow foods unique to the region. It is well known that food AI models are mostly trained on datasets that represent Western cultures, so the team creates and prepares over 4,000 images with proper annotations for four major Nigerian dish categories and five kinds of image degradation. To make sure the models being studied could identify both types of CP foods, the CNNAFCM was designed to test both the fresh and stale options. Instead of focusing only on one type of data, CNNAFCM uses data from traditional local foods, and is created for use in agricultural monitoring, recognizing foods, and analyzing diets in under-developed regions. By applying benchmarking to MobileNet, and LeNet-5, along with local data, we are showing that it is a robust convolutional neural network. Early findings suggest the model does a good job distinguishing between types of food and is able to generalize well when presented with unfamiliar foods. Thanks to this technology, agriculture now has better options for AI that honor differences in eating habits and allows for easier monitoring of food origins. This also makes it possible to connect Internet of Things systems to agriculture, create mobile health apps, and make aids for those with vision problems. The CNNAFCM framework acts as a flexible and aware model to help in classifying foods from various degradation. The project continues, and we are working on improvements like deploying and testing the system live on important data from different parts of the world. Being part of the congress will lead to new and valuable partnerships in global food AI research.

Keywords: Automatic Food Classification, Convolutional Neural Networks (CNN), Indigenous Nigerian Foods, Smart Agriculture, Cross-Cultural Food Recognition

ASSESSING THE ENVIRONMENTAL CONSEQUENCES OF PLANT PROTECTION MEASURES IN ALGERIAN ARID-ZONE CEREAL FARMING

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ABSTRACT

This study investigates phytosanitary practices in cereal cultivation within the Biskra region, located in the southeast of Algeria. Through field surveys involving 259 farmers, we calculated phytosanitary pressure indices (FTI and PPI). The survey results reveal that a majority of cereal farmers take measures to protect their crops, primarily against weeds. However, a diverse range of active ingredients, including Cloquintocet-Mexyl, Clodinafop-Propargyl, and 2,4-D, were identified. Fourteen active ingredients were classified as moderately dangerous (Class II) according to the WHO.

Despite efforts to combat pests, the study highlights an uncontrolled use of pesticides, evidenced by non-compliance with recommended application rates, ignorance of recommended application intervals, and improper dosage of pesticides. Limited supervision further exacerbates this issue, particularly among cereal producers with low levels of education. To assess the consequences of these practices, we calculated the Treatment Frequency Indicator (TFI) and the Phytosanitary Pressure Index (PPI). These indices categorized study sites based on the risk levels associated with pesticide use by cereal farmers.

Our findings indicate higher total Plot TFI (combining herbicide and non-herbicide TFI) for durum wheat and soft wheat compared to barley. Notably, Ain Naga exhibits very strong phytosanitary pressure (IPP=2.60), while El Feidh, El Outaya, Mlili, Oumeche, and Ourllal experience strong pressures. Doucen, on the other hand, presents a moderate pressure. Such practices may contribute to reduced cereal yields and environmental pollution, impacting human and animal health through bioaccumulation and biomagnification. Addressing these challenges necessitates comprehensive training, awareness programs, and continuous monitoring of cereal farmers to ensure sustainable agriculture, safeguarding human and animal health, and protecting the environment.

Keywords: cereals, phytosanitary practices, survey, PPI, FTI, arid region.

INFLUENCE OF LOCAL–IMPORTED WHEAT MIXTURES ON COUSCOUS QUALITY

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ABSTRACT

An experimental study was carried out on El-Baraka brand couscous, to determine the extent of the effect of the blending technique (combination) between two types of wheat (local and imported) on the quality characteristics of the finished product.

The results of physicochemical analyses of local and imported durum wheat (dockage, specific weight, thousand kernel weight, moisture content, etc.), as well as those of the semolina obtained from their millings (particle size, moisture content, ash content, color index, gluten, etc.), showed that they complied with Algerian standards, with a quality superiority in favor of imported wheat. Physicochemical analyses (particle size, color indices, water content, ash content, etc.), culinary analyses (swelling index, post-cooking weight, etc.) and sensory tests on the couscous produced from the blending proved that it complied with Algerian standards, with superiority over the control couscous made from local wheat, and that it largely retained the quality characteristics of the control couscous made from imported wheat.

Keywords: couscous, blending, quality, physicochemical analysis, culinary analysis, sensory testing.

ASSESSMENT OF WATER QUALITY FOR LIVESTOCK CONSUMPTION

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ABSTRACT

This study aimed to evaluate the sanitary quality of drinking water for livestock in the municipality of Ain Naga by identifying biological, chemical, and physical hazards to assess the level of risk. A field survey was conducted across several farms to analyze water sources and watering systems, focusing on the origin of the drinking water, the number and hygiene of drinking troughs, and their usage capacity.

Bacteriological analyses performed on water samples collected from boreholes, water sources, and drinking troughs indicated the complete absence of total coliforms, fecal coliforms, total germs, and fecal streptococci or enterococci. These findings confirm that the drinking water in Ain Naga has good bacteriological quality.

Physicochemical analyses showed that while boreholes and water sources had normal levels of physical parameters and chemical substances, watering troughs contained minerals such as chlorides, sulfates, ammonium, and nitrates at levels exceeding regulatory and international standards. This suggests that the physicochemical quality of drinking water in this municipality is only moderate.

The survey linked these results to several contributing factors, including inadequate hygiene practices, traditional watering system installations, lack of maintenance of water pipelines, and excessive use of pesticides and fertilizers in farming areas. These conditions contribute to the contamination of drinking water, affecting livestock health and production.

Based on these findings, the study recommends improving maintenance of watering installations to ensure the hygiene of materials in direct contact with drinking water and conducting annual water quality analyses. These measures are essential for protecting animal health, ensuring good farming practices, and enhancing livestock production in Ain Naga.

Keywords: drinking water quality, livestock health, bacteriological analysis, physicochemical contaminants, farm management.

FEEDING THE FUTURE METROPOLIS: VERTICAL FARMING AS URBAN INFRASTRUCTURE

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ABSTRACT

The aim of this research is to understand if vertical farming could be key to urban infrastructure in large cities by increasing food supply, decreasing environmental issues, and helping to sustain the city. Research and findings show that vertical farming produces the same types and amounts of food as traditional farming, however, it requires significantly less water and land. It has been found that using vertical farming can raise local food production by up to 30%, improving the stability of the food chain in cities. In addition, looking at the social and economic effects, vertical farming may open up new jobs and strengthen nearby business communities. These discoveries are important when it comes to healthcare, since easier access to fresh produce for those in cities often contributes to a better diet and lowers the risk of diseases related to nutrition. This study suggests that making vertical farming a part of urban planning can boost community well-being, make cities more attractive, and set a sustainable pathway for city development. The study suggests that having policies that help startups invest in vertical farming can help solve food security and health challenges in urbanized areas.

Keywords: Vertical Farming; Urban Agriculture; Sustainable Food Systems; Urban Infrastructure.

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ARCHITECTURAL LOGISTICS FOR THE URBAN FOOD GRID: COLD CHAINS, STORAGE, AND DESIGN

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ABSTRACT

The study explores ways that architectural logistics can improve the food grid in urban areas by improving cold chain systems and storage. The key research issue to consider is that existing transport and infrastructure supporting temperature-sensitive food are poor, putting at risk food quality and safety. An analysis of the cold chain, warehousing, and urban deliveries brings out flaws in the existing ways they are managed. Current systems do not handle the task of food distribution well, which results in a lot of wasted food and possible risks to the public. It is proven in the research that implementing new designs for storing and handling food can create more chances for food access and higher food quality, which helps protect people's health. It shows that making sure urban infrastructure works with local food distribution can play a role in improving public health outcomes. The findings can greatly affect healthcare by providing a way to keep food safe as part of urban planning, leading to improved health for urban communities. Through the relation between healthy urban planning and improved distribution of food, the research encourages stronger public health policies for urban planning.

Keywords: Urban Food Logistics; Cold Chain Infrastructure; Architectural Design for Food Systems; Perishable Food Storage; Food Distribution Networks.

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ZERO-KILOMETER ARCHITECTURE: DESIGN STRATEGIES FOR HYPERLOCAL FOOD SYSTEMS

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ABSTRACT

This study focuses on finding effective ways of designing zero-kilometer architecture in urban areas to foster both local food supply and demand, serving the dual purpose of lowering carbon emissions and improving ecological sustainability. By using a mixed methods approach, the study combines information from community polls and architect's recommendations with analyzing the food supply routes and their effects on the environment. The main takeaway is that engaging communities in urban food farming and buying foods locally helps people collaborate and ensures less CO2 is emitted during transport of goods. As a result, these research findings highlight that urban local food production could ensure more food security, promote good nutrition, and thus support the overall health of city dwellers. It shows how architectural design, food sustainability, and health are all linked, so this study can guide and assist those working for healthier communities. All in all, the study calls for designing cities with both architecture and sustainable food systems, saying that doing so forms a base for creating healthy urban areas and sturdy networks of food supply.

Keywords: Zero-Kilometer Architecture; Hyperlocal Food Systems; Sustainable Urban Design; Local Food Production; Food-Energy-Water Nexus.

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PUBLIC SPACE AS FOOD INFRASTRUCTURE: ACTIVATING PARKS AND PLAZAS FOR EDIBLE URBANISM

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ABSTRACT

Its purpose is to look at the role of parks and plazas in changing the urban environment by turning them into food infrastructures that increase edible urbanism and deal with problems related to food access and maintaining sustainable cities. The study has shown that public areas in those communities are not well-used for urban agriculture, though their sizes and qualities could be suitable for this purpose. The study looks at case studies of successful urban farms to find out which methods encourage farming in cities and share examples where people are involved. According to the study, urban agriculture helps improve health results for communities by making fresh foods available, encouraging unity, and supporting better care of the environment. The findings add to the field of public health in urban design by suggesting that having food systems in public spaces can improve food security and support better health for residents. As a result of this study, new guidelines and strategies in healthcare are now being created, based on the strong connection between the environment and health. It encourages different groups to join forces to support the development of communities that benefit us and the planet.

Keywords: Edible Urbanism; Public Space Design; Urban Agriculture; Productive Landscapes; Multifunctional Urban Spaces.

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VALUE ADDED PRODUCT DEVELOPMENT INCORPORATED WITH HEMP SEED

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ABSTRACT

In the recent years increasing interest in vegetarian diets has been observed, a major problem in this type of diet is to provide the appropriate amount of protein [1] . Value addition of food is current most talked topic because of increasing nutritional awareness among consumers today [1] . An investigation will be conducted to develop protein rich multi-millet khakhra incorporated with hemp seed. The seeds of hemp (cannabis sativa L.) have been a significant source of food for thousands of years. In recent years, hemp has not been thoroughly explored for its nutritional potential due to the mistaken belief regarding the cannabis plants. Two variations Will be prepared referencing standard recipe. Variation 1 will be prepared using whole wheat flour-40g, sorghum-20, fingermillet-10g, kasuri methi-5g, hemp seed powder 20g, oil-5g, variation 2 will be prepared using whole wheat flour-40g, sorghum-15g, fingermillet-10g, kasuri methi-5g, hemp seed powder-25g, oil-5g. The product will be subjected to sensory evolution by semi trained panel members using 9 point hedonic on 100 panelists. According to the secondary data product having 25g of hemp seed powder will be most preferred one [2] . khakhras can be eaten as a snack at any time of the day. hemp seed powder incorporated in it enhances its nutritive value and makes it more nutritious. It is suitable for consumption of all the age group.

Keywords: cannabis sativa, hemp, protein, seed.

ASSESSING THE SUITABILITY OF SURFACE WATER FROM BIN EL OUIDANE RESERVOIR FOR AGRICULTURAL IRRIGATION IN MOROCCO

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ABSTRACT

Assessing the quality of surface water in reservoirs is essential for the sustainable management of water resources, especially in regions where such water is used for multiple purposes, including irrigation, drinking supply, and recreation. This study presents a detailed physicochemical and microbiological evaluation of the surface waters of the Bin El Ouidane reservoir, located in the Tadla-Azilal region of Morocco - an area where agriculture is highly dependent on water availability and quality.

Water samples were collected from multiple locations and depths during two contrasting seasons to capture both spatial and temporal variability. Physicochemical parameters analyzed included temperature, pH, electrical conductivity, turbidity, dissolved oxygen, nitrates, phosphates, and selected heavy metals. Microbiological quality was assessed by quantifying fecal indicator bacteria, namely Escherichia coli and total coliforms.

The findings revealed significant seasonal variations. Elevated levels of nitrates and phosphates point to a potential risk of eutrophication, which could affect downstream agricultural productivity and soil health. While heavy metal concentrations remained below critical thresholds, their presence suggests possible localized contamination. Microbiological results indicated episodic fecal pollution, which could pose health risks if the water is used for irrigating crops consumed raw.

These results highlight the need for improved water quality monitoring and protection strategies to safeguard both public health and agricultural sustainability in the region.

Keywords: Water quality, Bin El Ouidane reservoir, irrigation, agricultural water use, physicochemical analysis, microbiological contamination, Morocco

LACTIC ACID BACTERIA: FUNCTIONAL DIVERSITY AND EMERGING APPLICATIONS

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ABSTRACT

Lactic acid bacteria are a group of ubiquitous, heterogeneous, and ecologically diverse bacteria.They are mainly responsible for the production of lactic acid as a by-product. These microorganisms are of significance due to the multifaceted roles they play in the agricultural, food, and clinical sectors. Advancements in the domains of genetics, molecular biology, physiology and biochemistry have provided new insights and applications for these bacteria. The objective of this study is to underscore the multifaceted applications of LAB and their pivotal role in confronting contemporary challenges.

Keywors : Fermentation, Food Biotechnology, lactic acid bacteria, functional diversity

CONTRIBUTION OF SEED MORPHOMETRIC CHARACTERIZATION TO THE IDENTIFICATION OF INDIGENOUS MOROCCAN GRAPEVINE CULTIVARS

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ABSTRACT

The study of grapevine seed morphology provides valuable insights into the domestication level of cultivars and the extent of their selection. In this context, a morphometric characterization was carried out on eleven of the most widespread indigenous grapevine cultivars from the northwestern region of Morocco. These cultivars were identified during field surveys conducted in the Ouezzane region, with three biological replicates per cultivar. For morphometric analysis, twenty seeds per cultivar were cleaned, air-dried at ambient temperature, and photographed. The images were processed using SuperAmpelo measurement software. Following calibration, three morphometric parameters were measured for each seed: total length, total width, and beak length. Additionally, the Stummer index—defined as the ratio of seed width to total length—was calculated for each seed.

Our results showed that beak length and the Stummer index were the most discriminating parameters among the studied cultivars. Furthermore, the Stummer index enabled the classification of all cultivars into three distinct groups. The cultivar Zbarjel exhibited the lowest ratio (0.55), closely aligning with the cultivated compartment of Vitis vinifera, which suggests a more advanced evolutionary stage and, therefore, earlier domestication. In contrast, the cultivar Fekass Khal showed the highest ratio (0.66), indicating a relatively recent domestication process. The remaining cultivars fell into an intermediate category, with ratios that were not sufficiently distinctive for clear classification.This study contributes valuable data to the identification and characterization of Morocco's indigenous viticultural heritage, offering new perspectives on the domestication history of local grapevine cultivars.

Keywords: Grapevine (*Vitis vinifera*); Seed Morphometry; Indigenous Cultivars; Morocco; Morphological Characterization.

FIRST-GENERATION SCREENING OF GAMMA-IRRADIATED STRAWBERRY PLANTS FOR AGRONOMIC AND QUALITY TRAITS IN MOROCCO

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ABSTRACT

Strawberries are among the most widely consumed seasonal fruits globally and hold considerable economic importance. This study aims to improve the yield and quality of Moroccan strawberries by selecting high-performing plants. A total of 3 000 plants plants were subjected to gamma irradiation and cultivated under controlled environmental conditions. In this first generation, 1425 plants were selected based on superior pomological and biochemical characteristics, including high fruit sugar content (°Brix), acceptable acidity levels, natural pH, attractive fruit colour, and overall plant vigour. Comprehensive data on plant growth parameters, fruit size and weight, °Brix, acidity, pH, and colour reflectance values (L*, a*, b*) were collected and analysed using SASS software. The findings of this study provide valuable insights for Moroccan strawberry growers and breeders, supporting the identification and development of varieties well-adapted to local conditions and market requirements, and contributing to the goal of national self-sufficiency.

Keywords: Strawberry (*Fragaria* × *ananassa*) ; Gamma Irradiation ; First Generation; Mutant Selection; Pomological Traits ; Biochemical Traits.

COLOADED THERMOSENSITIVE SYSTEM OF IRINOTECAN AND CURCUMIN NANO-VESICLE FOR COLORECTAL CANCER TARGETING, *in vitro* and *in vivo* INVESTIGATION

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ABSTRACT

The aim of study was to develop the thermoresponsive nanovesicles loaded drug delivery system for colorectal cancer targeting. Irinotecan and curcumin loaded nanoparticles (IRT-CUR-NTs) were incorporated into poloxamer (P407, P188) based system (IRT-CUR-NTG) that was administered by rectal route. IRT-CUR-NTs was optimized in terms of particle size, zeta potential and polydispersity index. Irinotecan and curcumin entrapment efficiency was also calculated. IRT-CUR-NTs were characterized by performing fourier transform infrared spectroscopy, differential scanning calorimetry, transmission electron microscopy. IRT-CUR-NTG was prepared and pH, gelation time, gelation temperature was noted. Moreover, *in vitro* drug release study and pharmacokinetic study was performed to check the drug release patterns. Additionally *in vitro* anticancer analysis was performed on HT29 cell lines. *In vivo* anticancer analysis demonstrated the significant reduction in tumor size and tumor volume after treatment with IRT-CUR-NTG. Results obtained from analysis indicate that prepared thermosensitive could be promising system in treatment of colorectal cancer but further analysis are required to prove its further efficacy.

Keywords: Colorectal, Curcumin, Irinotecan, Nanoparticles, Thermosensitive, Poloxamer

REVOLUTIONIZING AGRICULTURE: THE SYNERGY OF IoT AND AI IN CROP MONITORING

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ABSTRACT

The convergence of the Internet of Things (IoT) and Artificial Intelligence (AI) is transforming traditional agricultural practices into smart, data-driven systems. This research presents a comprehensive framework that integrates IoT sensor networks with advanced machine learning algorithms to enhance crop monitoring and farm productivity[1,2].

In the proposed system, a network of IoT sensors—including soil moisture probes, temperature and humidity sensors, and multispectral imaging devices—is deployed across agricultural fields to continuously monitor critical environmental and crop parameters[2,4]. The collected data is transmitted to a cloud-based platform where AI models process the information in real-time to detect anomalies, predict pest or disease outbreaks, and recommend timely interventions such as irrigation, fertilization, or pesticide application.

Machine learning techniques play a pivotal role in analyzing the vast amount of data generated. In the proposed system, Random Forest is utilized for disease and pest prediction, while regression models forecast crop yields and soil nutrient levels[1,3]. Random Forest demonstrates an R^2 score of 0.92. Regression models are employed to forecast crop yields and soil nutrient levels, with Linear Regression achieving a mean absolute error (MAE) of 6.7%. These models effectively support real-time decision-making in precision agriculture[1,3].

Infuture, K-means clustering, an unsupervised learning method, can be utilized to segment agricultural zones based on soil and crop conditions, enabling targeted interventions. Additionally, time-series forecasting models such as Long Short-Term Memory (LSTM) networks may be used to predict weather trends and optimize irrigation schedules. The implementation of this IoT-AI synergy demonstrates significant improvements in early disease detection, resource optimization, and overall farm management[2,3].

Keywords: Smart Agriculture, Internet of Things (IoT), Random Forest, Machine Learning, Precision Farming, Crop Monitoring.

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THE ROLE OF AGRICULTURAL TECHNOLOGY USE IN ENHANCING SUSTAINABLE FOOD SYSTEMS OF SMALLHOLDER SOYBEAN FARMING IN NORTHERN GHANA

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ABSTRACT

Agriculture remains the backbone of livelihoods for millions of smallholder farmers, especially in Northern Ghana, where poverty is widespread. However, these farmers face climate variability, limited resources, and fluctuating market conditions. Despite the potential of agricultural technology use to improve productivity, many smallholder farmers have yet to fully utilize them. This research explores how the use of agricultural technology impacts sustainable soybean food systems, focusing on social, economic, and environmental dimensions. Drawing on data collected through structured interviews with 280 soybean farmers, the study employs a three-stage least squares regression to understand these relationships in depth. The findings reveal that using agricultural technology is strongly linked to better social (2.464, $p<0.05$), economic (1.694, $p<0.05$) and environmental (2.713, $p<0.05$) sustainability. Interestingly, the study also highlights some complexities. Larger scale operations (0.281, $p<0.05$) and higher education levels (0.014, $p<0.05$) were associated with lower social outcomes, suggesting that expanding farm operations or education alone may not guarantee improved social conditions. Conversely, farmers who kept records (4.996, $p<0.05$) and those with secure landholding status (3.210, $p<0.05$) experienced better social sustainability, indicating that management practices and tenure security matter significantly. A surprising result was the consistently negative association between participation in agricultural development programmes (ADP) and all sustainability outcomes (Social- -3.634, Economic- -3.043 and Environmental- -3.377, $p<0.05$), which raises questions about the relevance or implementation effectiveness of these programmes in the local context. For policymakers and stakeholders, such Ministry of Food and Agriculture, the Environmental Protection Agency and Agriculture-based NGOs, efforts should focus on removing barriers to effective technology use, improving the design and delivery of development programmes, and supporting farmers with tools that balance productivity with wellbeing. Such strategies are crucial for building a resilient, sustainable soybean food system that can thrive despite the challenges faced by smallholder farmers in Northern Ghana.

Keywords: Agricultural Technology Use, Sustainable Food System, Soybean Farming, Three-Stage Least Squares Estimation, Northern Ghana

SPIRULINA TO THE RESCUE: BOOSTING TILAPIA GROWTH UNDER PESTICIDE STRESS

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ABSTRACT

Sumithion, a synthetic organophosphate, is extensively used in agricultural land as an insecticide. It is also used in larval-rearing ponds to control tiger bugs (*Cicindela* spp.). The indiscriminate use poses a potential threat to many non-target organisms, including fish. Sumithion toxicity alters numerous physiological, biochemical, and hematological parameters which eventually affect growth, reproduction, immunity, etc. An experiment was performed to observe the role of Spirulina in reducing the detrimental effects and damage in Nile tilapia (*Oreochromis niloticus*) due to sumithion exposure. Four treatments namely Treatment-1 (Control), Treatment-2 (Sumithion; 0.3 mg/L), Treatment-3 (Spirulina; 50gm/kg), and Treatment-4 (Sumithion + Spirulina) were administered. The findings indicated that fish exposed to sumithion showed the least weight gain (WG), lowest specific growth rate (SGR), and the highest feed conversion ratio (FCR) among all treatments. Moreover, the intestinal parameters exhibited significant negative alterations. Whereas Spirulina-supplemented diet played a crucial role in counteracting the changes caused by sumithion toxicity. Nevertheless, Spirulina-supplemented diet exhibited significant enhancements in growth parameters (WG, SGR, FCR) and improved intestinal functions. The present study unveiled the implementation of dietary Spirulina to be an effective approach to mitigate sumithion-induced growth inhibition in Nile tilapia by improving intestinal morphology.

Keywords – aquaculture, pesticides, toxicity, bioremediation, Spirulina, Nile tilapia

PHYTOCHEMICAL ANALYSIS OF AVOCADO LEAVES AND TURMERIC

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ABSTRACT

This study reports the phytochemicals contained in aqueous extract prepared from avocado leaves and turmeric powder procured from Nsukka environment. The aim of the study was to investigate the qualitative phytochemicals present and to determine the total phenolic and flavonoids contents of avocado leaves and turmeric. Results showed reducing sugar strongly present, flavonoids, tannins, steroids, glycoside and saponins were mildly present. Result for turmeric extract showed flavonoids, phenols, alkaloids were moderately present, tannins, steroids, glycoside, reducing sugar were mildly present while saponin was absent. Extracts of avocado leaves and turmeric contains important medicinal bioactive compounds and it justifies their use in the traditional medicine for treatment of diseases. In conclusion, extracts of avocado leaves and turmeric studied were rich in phytochemicals with remarkable pharmacological and medicinal relevance.

Keywords: Aqueous extract, Phytochemical, Medicinal plants, Turmeric, Avocado leaves

ROLE OF URBAN PLANNERS IN PROMOTING ENERGY-EFFICIENT SCREEN HOUSE TOMATO PRODUCTION IN URBAN AREAS; A CASE STUDY OF YEWA NORTH LOCAL GOVERNMENT AREA OF OGUN STATE

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ABSTRACT

Urban planners play a crucial role in supporting sustainable urban agriculture practices. This study assessed the role of urban planners in promoting energy-efficient screen house tomato production in urban areas, with a case study of Yewa North Local Government Area of Ogun State. An experimental design was employed at the screen house of the Crop Production department, College of Agricultural Sciences, Olabisi Onabanjo University, Ayetoro, Ogun State. Three tomato varieties (Kerewa, Royal, and UC.82) were evaluated in a randomised complete block design with three replicates. Energy-related data, including manual, biological and chemical energy inputs and tomato yield as output, were collected and analysed using Analysis of Variance (ANOVA). The results showed significant variations in energy inputs across operations and varieties, with manual labor and chemical inputs being the most substantial contributors. Royal emerged as the most energy-efficient and economically profitable variety. This study highlights the importance of urban planners in promoting energy-efficient practices in screen house tomato production, contributing to sustainable urban food systems and economic development. The findings can inform urban planning policies and practices that support sustainable urban agriculture and energy-efficient food production.

Keywords: Urban Planners, Energy-efficient, Sustainable Urban Food System, Screen house.

NUTRITIONAL COMPOSITION AND HEALTH BENEFITS OF BITTER MELON

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ABSTRACT

Bitter melon which is typically known as bitter gourd with scientific name *Momordica charantia* belongs to the gourd family and has much resemblance with cucumber, pumpkin and zucchini. It is cultivated as edible fruit around the world and considered a staple in many types of Asian cuisine. It possessed distinct appearance, bitter taste and sharp flavor. Bitter melon is a great source of energy and several key nutrients including carbohydrates, vitamins, fiber and minerals. It has been associated with several health benefits due to presence of several phyto-nutrients. It has cancer-fighting properties, helps to reduce blood sugar and cholesterol levels. The phyto-nutrients extracted from bitter melon are supplemented into functional foods and functional beverages. Modern technologies like novel green ultrasound are adopted to extract phyto-nutrients from bitter melon and these phyto-nutrients are preserved using nanoencapsulation. Overall, bitter melons are good source of nutrient for supplementation in plant-based diets cand have wide applications against different metabolic syndrome diseases.

Keywords: Bitter Melon, Nutritional Composition, Plant-Based Diets, Health Benefits

HOSPITAL WASTEWATER AS A SILENT VECTOR: MICROBIAL CONTAMINATION AND ANTIBIOTIC RESISTANCE AT THE HUMAN HEALTH-ENVIRONMENT INTERFACE

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ABSTRACT

Hospital wastewater represents a complex matrix containing pathogenic microorganisms, antibiotic residues and chemical pollutants, posing serious risks to public health, food safety and ecosystems. This study, carried out in two hospitals in south-west Morocco, assessed the microbiological quality of the effluents and analyzed the antibiotic resistance profiles of the bacteria isolated. Results revealed high loads of fecal indicators (E. coli, enterococci, total and fecal coliforms) and pathogens such as Pseudomonas aeruginosa, Staphylococcus aureus and Klebsiella pneumoniae. Of the 75 strains isolated, 68% were multi-resistant, with high resistance to beta-lactams and quinolones. In particular, 47% of E. coli strains were producers of extended-spectrum beta-lactamases.

Statistical analyses (ANOVA, PCA, Chi² test) showed significant differences between the two hospitals in terms of bacterial loads and resistance profiles. The direct discharge of these untreated effluents into urban sewage systems increases the risk of contamination of water used for irrigation, thus exposing agricultural soils, crops and consumers. Faced with this problem, the study proposes the integration of advanced treatment techniques (such as electrocoagulation, bioactive filters or combined physico-chemical and biological processes) to reduce the microbial and chemical load of HWW, with a view to their safe reuse for agriculture, in particular irrigation, thus contributing to circular water management and food safety.

Anacyclus pyrethrum : UNE ESPECE MEDICINALE MENACEE ENTRE VALORISATION ETHNOBOTANIQUE ET CONSERVATION DURABLE

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RESUME

Anacyclus pyrethrum, plante médicinale endémique du Maroc, est depuis longtemps valorisée pour ses propriétés thérapeutiques, notamment en tant qu'analgésique, insecticide naturel et tonique du système nerveux. Cette espèce, riche en composés bioactifs, suscite un intérêt croissant en pharmacologie et en agronomie, mais fait face à une surexploitation préoccupante. Cette synthèse bibliographique examine les connaissances actuelles sur ses propriétés phytochimiques et pharmacologiques, ses usages traditionnels, sa biologie reproductive, ainsi que son statut de conservation. L'objectif est de contribuer à une meilleure compréhension scientifique de cette espèce et de proposer des pistes de valorisation durable intégrant la protection de la biodiversité et la régulation de sa filière d'exploitation au Maroc.

Mots clés : *Anacyclus pyrethrum ; Plante Médicinale ; biodiversité ; conservation*

VALORIZATION OF AGRICULTURAL WASTE IN SUSTAINABLE BIOCOMPOSITES: ENHANCING MECHANICAL PROPERTIES WITH NATURAL FIBER REINFORCEMENTS

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ABSTRACT

In response to the rising demand for sustainable materials and the depletion of non-renewable resources, this study focuses on developing high-performance bio-composites reinforced with agricultural residues, specifically utilizing coconut fibers as a low-cost, thermally stable natural filler in polypropylene matrices to create eco-friendly materials with enhanced mechanical properties. Bio-composites, consisting of a matrix that binds the structure and transfers loads, and natural fibers that provide strength and stiffness, face a key challenge in the poor interfacial adhesion between the hydrophilic fibers and hydrophobic thermoplastic matrices. To improve fiber-matrix compatibility and overall performance, chemical treatments such as alkaline processing were employed.

This study investigates the effect of fiber length on the mechanical behavior of polypropylene reinforced with coconut fibers, using extrusion and injection molding processes. A detailed experimental analysis encompassing structural, morphological, thermo-mechanical, and moisture absorption tests was conducted to determine the optimal fiber configuration. The use of agricultural biomass as functional fillers, combined with tailored coupling agents and processing methods, resulted in composites with significantly enhanced properties, including a more than 70% increase in Young's modulus, improved thermal stability, and reduced water absorption. These results underscore the potential of valorizing agricultural waste to develop high-performance, bio-based materials, positioning such bio-composites as sustainable alternatives to petroleum-based plastics for applications in agriculture, packaging, and the processing industry.

Keywords: Biocomposites, natural fibers, agricultural residues, polypropylene, thermomechanical properties, sustainability, biomass valorization,

UNIVERSITY STUDENTS' MINDFULNESS LEVELS AND DEPRESSION LEVELS AND THEIR RELATIONSHIP WITH THEIR TENDENCY TO RECEIVE PSYCHOLOGICAL SUPPORT

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ABSTRACT

In recent years, growing attention has been directed toward understanding the psychological factors that influence young adults' willingness to seek mental health support, particularly in the context of increasing mental health challenges among university populations. This study aims to explore the relationship between university students' levels of mindfulness and depression, and how these psychological factors influence their tendencies to seek professional psychological help. The research is grounded in the increasing recognition of mindfulness and depression as critical determinants of psychological well-being among young adults, particularly within the university population. A total of 202 undergraduate students aged 18 and above participated in the study. Data were collected using the Demographic Information Form, the Five Facet Mindfulness Questionnaire (FFMQ), the Beck Depression Inventory (BDI), and the Attitudes Toward Seeking Professional Psychological Help Scale–Short Form (ATSPPH-SF). In addition to descriptive statistics, Pearson correlation analyses were conducted to examine the relationships among the key variables. The findings revealed a statistically significant and positive correlation between mindfulness and the tendency to seek psychological help ($r = 0.273$; $p < 0.01$), indicating that higher levels of mindfulness are associated with greater openness to seeking professional support. However, the relationship between depression levels and help-seeking tendencies was found to be non-significant ($r = 0.015$; $p = 0.835$). These results suggest that individuals with higher mindfulness may possess greater self-awareness and acceptance, which may facilitate adaptive help-seeking behaviors. The study highlights the potential value of mindfulness-based interventions in promoting early psychological support and enhancing mental health outcomes among university students.

Keywords: Mindfulness, depression, psychological support

EXAMINING THE EMOTIONAL REFLECTIONS OF VOICE BEHAVIORS IN ORGANIZATIONS: AN EMPLOYEE PERSPECTIVE

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ABSTRACT

This study aims to examine the impact of voice behaviors (employee voice and employee silence) appearing in the organizational context on employees' emotional states. Voice behaviors are categorized into two main groups: employee voice (voice behavior) and employee silence (silence behavior). Employee voice refers to proactive communication behaviors where individuals participate in organizational processes, express opinions, and share suggestions. In contrast, employee silence reflects the withholding of knowledge, thoughts, or concerns for various reasons.

A review of the existing literature shows that voice behaviors are often examined in terms of their antecedents or organizational outcomes, while their emotional reflections on employees have been relatively underexplored. This study aims to fill this gap by comprehensively analyzing the positive (feeling good, feeling comfortable, excitement) and negative (feeling bad, disappointment, feeling worthless) emotional impacts of voice behaviors on employees.

The study was conducted using a qualitative research method, adopting a phenomenological approach. In-depth semi-structured interviews were carried out with 43 academicians working at public universities in the Marmara Region with at least one year of work experience. The findings reveal that voice behaviors directly affect employees' emotional states. Employee voice contributes to participants feeling valued and motivated, whereas employee silence leads to feelings of disappointment, exclusion, and worthlessness.

The findings of the study indicate that a supportive communication climate in organizations enhances employees' emotional well-being and strengthens organizational commitment. In this context, promoting employee voice, valuing their emotions and thoughts, and evaluating their contributions are considered strategic necessities for sustainable success and satisfaction.

Keywords: Employee Voice, Employee Silence, Voice Behaviors, Emotional State

ÖRGÜTLERDE SES DAVRANIŞLARININ DUYGUSAL YANSIMALARI: ÇALIŞANLARIN PERSPEKTİFİNDEN BİR İNCELEME

ÖZET

Bu çalışma, örgütsel bağlamda ortaya çıkan ses davranışlarının (çalışan sesi ve çalışan sessizliği), çalışanların duygu durumları üzerindeki etkilerini incelemeyi amaçlamaktadır. Ses davranışları, çalışan sesi (voice behavior) ve çalışan sessizliği (silence behavior) olmak üzere iki temel kategoriye ayrılmaktadır. Çalışan sesi, bireylerin örgütsel süreçlere katılım sağlamak, görüş ve önerilerini dile getirmek amacıyla sergiledikleri aktif iletişim davranışlarını tanımlarken; çalışan sessizliği, sahip olunan bilgi, düşünce veya endişelerin çeşitli sebeplerle dile getirilmemesi durumunu yansıtmaktadır.

Mevcut literatür incelendiğinde, ses davranışlarının genellikle öncülleri veya örgütsel sonuçları üzerinde durulduğu; çalışanların duygusal yansımalarına yeterince odaklanılmadığı görülmektedir. Bu çalışma, literatürdeki bu boşluğu doldurmak amacıyla ses davranışlarının çalışanların duygu durumları üzerindeki olumlu (iyi hissetme, rahat hissetme, heyecan) ve olumsuz (kötü hissetme, hayal kırıklığı, değersiz hissetme) etkilerini kapsamlı bir şekilde incelemeyi hedeflemektedir.

Nitel araştırma yöntemiyle yürütülen bu çalışmada, fenomenolojik yaklaşım benimsenmiş olup, Marmara Bölgesi'ndeki devlet üniversitelerinde görev yapan, en az bir yıllık iş deneyimine sahip 43 akademisyenle yarı yapılandırılmış görüşmeler gerçekleştirilmiştir. Elde edilen bulgular, ses davranışlarının çalışanların duygusal durumları üzerinde doğrudan etkili olduğunu göstermektedir. Çalışan sesi, katılımcıların kendilerini değerli hissetmelerine ve motive olmalarına katkı sağlarken; çalışan sessizliği ise hayal kırıklığı, dışlanmışlık ve değersizlik hissiyatına yol açmaktadır.

Araştırma bulguları, örgütlerde destekleyici bir iletişim ikliminin, çalışanların duygusal iyilik hallerini artırarak örgütsel bağlılığı güçlendireceğini ortaya koymaktadır. Bu doğrultuda, çalışanların sesliliğini teşvik eden, duygu ve düşüncelerini önemseyen ve değerlendiren bir örgüt iklimi, sürdürülebilir başarı ve memnuniyet için stratejik bir gereklilik olarak değerlendirilmektedir.

Anahtar Kelimeler: Çalışan Sesi, Çalışan Sessizliği, Ses Davranışları, Duygu Durumu

A STUDY ON THE WORK VALUES OF GENERATİON Z EMPLOYEES

Z KUŞAĞI ÇALIŞANLARIN ÇALIŞMA DEĞERLERİ ÜZERİNE BİR İNCELEME

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ABSTRACT

This study aims to examine the concept of work values, which is widely discussed in the literature, in the context of Generation Z. Within the scope of the study, work values are defined as the set of attitudes and behaviors that individuals develop in line with the value systems of the society they belong to and adopt in order to achieve the goals they set in their work life.

There are many studies conducted on Generation Z at national and international levels, and these studies are generally aimed at describing the general characteristics, tendencies and expectations of this generation. However, the number of studies on the values and expectations of this generation regarding work life is quite limited. When the existing literature is examined, it is seen that the studies mainly focus on Generation Z students; however, the research on Generation Z individuals who are actively involved in the labor market is limited. This situation can be associated with the fact that Generation Z is just starting to enter the work life.

Understanding the work values and priorities of Generation Z, who are expected to assume more active roles in work life in the coming years, is important in terms of both increasing the satisfaction and loyalty of employees at the individual level and structuring human resources policies more effectively at the institutional level. In this context, this study, which is expected to make an original contribution, aims to examine the work values of Generation Z employees in a comprehensive manner.

The main purpose of the study is to reveal the factors that shape the work values of Generation Z employees based on their experiences in work life; to deeply analyze how these values are interpreted, in which contexts they are addressed, and what kind of expectations they have from work life. In this context, the phenomenological approach, which is one of the qualitative research methods, was adopted and semi-structured in-depth interviews were conducted with 25 Generation Z employees who have at least two years of work experience.

In line with the findings obtained, the work values of Generation Z, the factors that shape these values, their expectations about work life, and the possible transformations they may bring about in work life in the future were analyzed. This report includes the findings and results reached within the scope of the research conducted.

Keywords: Value, Generation Z, work values.

A STUDY ON THE REASONS FOR NOT IMPLEMENTING IN-CLASS SCIENCE EXPERIMENTS

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ABSTRACT

Experimental activities in science teaching have an important place in developing students' scientific process skills and concretizing abstract concepts. However, studies have shown that teachers do not implement science experiments in the classroom sufficiently. The aim of this report is to determine why science teachers avoid conducting science experiments and to discuss the factors behind this situation. In this study conducted with a qualitative research design, semi-structured interviews were conducted with 20 science teachers working in different schools. The obtained data were analyzed using the content analysis method. The findings show that the reasons why teachers avoid conducting experiments are multidimensional. The most frequently mentioned reasons include inadequate laboratory infrastructure, time constraints, student discipline problems, security concerns, and the intensity of the curriculum. In addition, factors such as teachers not receiving sufficient in-service training on experimental methods, difficulties in obtaining experimental materials, and failure to integrate experiments into the measurement-evaluation process were also determined. In addition, some teachers think that the contribution of experiments to the teaching process is limited and that conducting experiments uses teaching time inefficiently. These findings reveal that in order to increase experimental applications in science teaching, teachers should be supported, school infrastructure should be strengthened and experiments should be given more place in teaching programs. The study aims to present solution suggestions for increasing the quality of science education by making the obstacles faced by teachers visible.

Keywords: Science teaching, experimental activities, teacher opinions, obstacles, laboratory use

EXAMINATION OF THESIS CONDUCTED ON SEXUAL ABUSE IN TURKEY BETWEEN 2014 AND 2024 THROUGH DOCUMENT ANALYSIS METHOD

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ABSTRACT

Aim

The rate of sexual abuse cases in Turkey has been increasing over the years. Studies conducted on sexual abuse are of great importance in terms of prevention and intervention. In this context, the aim of this research is to examine the theses conducted between 2014-2024 on individuals who were victims of sexual abuse, and the types of prevention and intervention studies conducted in the National Thesis Center database of the Council of Higher Education.

Methods

Document analysis, one of the qualitative research methods, was used in this study. The findings were analyzed through content analysis methods. The theses were retrospectively examined in terms of their fields of study, types, research models, and gender distribution.

Findings

According to the research results, 55 theses were reached. The distribution of the theses by field of study was as follows: Psychiatry (16), Forensic Medicine (15), Psychology (12), Social Work (6), Sociology (4), Physiotherapy and Rehabilitation (1), and Nursing (1). Twenty of the theses reached were conducted as qualitative, 19 retrospective, 13 quantitative and 2 mixed methods (qualitative and quantitative). Twenty-five of the theses were conducted as descriptive, 28 relational, 1 descriptive and relational, and 1 intervention program. The gender distribution of the group studied in the theses was 78.03% female and 21.97% male

Conclusion

Research conducted in recent years has revealed that with the increasing visibility of sexual abuse cases, its multidimensional effects and the need for interdisciplinary intervention have become evident.

Keywords: Sexual abuse, thesis analysis, abuse victims, retrospective research

TÜRKİYE'DE 2014-2024 YILLARI ARASINDA CİNSEL İSTİSMARA UĞRAYAN BİREYLER İLE İLGİLİ YÜRÜTÜLEN TEZLERİN DOKÜMAN ANALİZİ YÖNTEMİ İLE İNCELENMESİ

ÖZET

Amaç

Türkiye'de cinsel istismar vaka oranları yıllar içerisinde artmaktadır. Cinsel istismara yönelik yürütülen çalışmalar istismarın önlenmesi ve istismara müdahale bağlamında önem arz etmektedir. Bu doğrultuda bu araştırmanın amacı cinsel istismar mağduru bireyler ile ilgili 2014-2024 yılları arasında yürütülen ve Yüksek Öğretim Kurumu Ulusal Tez Merkezi veri tabanında yer alan tezlerin ve ne gibi önleme ve müdahale çalışmalarının yürütüldüğünün incelenmesidir.

Gereç ve Yöntem

Araştırmada nitel araştırma yöntemlerinden doküman analizi kullanılmıştır. Elde edilen bulgular ise içerik analizi yöntemi ile incelenmiştir. Çalışmada, yayınlanan tezlerin hangi ana bilim dallarında yer aldıkları, türleri, araştırma modelleri ve cinsiyete göre dağılımı retrospektif olarak incelenmiştir.

Bulgular

Araştırma sonuçlarına göre, 55 tez çalışmasına ulaşılmıştır. İncelenen tezlerin ana bilim dalları sırasıyla Psikiyatri(16), Adli Tıp(15), Psikoloji(12), Sosyal Hizmet(6), Sosyoloji(4), Fizyoterapi ve Rehabilitasyon(1), Hemşirelik(1) olarak saptanmıştır. Ulaşılan tezlerin 20'si nitel, 19'u retrospektif, 13'ü nicel ve 2'si karma yöntem (nitel ve nicel) olarak yürütülmüştür. Tezlerin 25'i betimsel, 28'i ilişkisel, 1'i betimsel ve ilişkisel, 1 'i müdahale programı şeklinde yürütülmüştür. Tezlerde çalışılan grubun cinsiyet dağılımı %78,03'ü kadın; %21,97'si erkek şeklindedir.

Sonuç

Son yıllarda yapılan araştırmalar, cinsel istismar olgularının artan görünürlüğüyle birlikte, çok boyutlu etkilerinin ve disiplinlerarası müdahale gereksiniminin belirginleştiğini ortaya koymaktadır.

Anahtar Kelimeler: Cinsel istismar, tez analizleri, istismar mağdurları, retrospektif araştırma

THE EFFECT OF CONCEPT CAFES ON SPATİAL PERCEPTİON: THE CASE OF DUDU FİRİN-KAHVE

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ABSTRACT

This research aims to evaluate the effects of coffee spaces on user preferences in the context of spatial and visual perception components. Today, coffee spaces have become public interior spaces that stand out with their multidimensional functions such as socialization, rest, experience and aesthetic satisfaction, beyond being just a consumption area. In this context, the relationship between users' perception of a space and the physical elements used in interior design constitutes an important research area in terms of the discipline of interior architecture. This study aims to examine the effects of physical design parameters that affect users' visual-spatial perceptions on user preferences.

The coffee shop named “Dudu Fırın-Kahve” located in Karatay district of Konya province was chosen as the application area of the research. The place attracts attention in terms of offering a nostalgic and aesthetic experience to the user with its location that establishes integrity with its surroundings at an important point in the historical environment of Konya. This structure, located around Bedesten, one of the historical centers of Konya, brings together traditional architectural elements and contemporary interior arrangements, both keeping the cultural heritage alive and serving as a current social meeting point. In this context, Dudu Fırın place constitutes an original example in terms of evaluating the relationship between spatial perception and user preference.

The study analyzed how the physical characteristics of the space – parameters such as shape, proportion, texture, color, light – are reflected in the user perception. Dudu Fırın was chosen as a sample due to both the richness offered by its historical context and its high popularity among users. In this respect, the study offers the opportunity to evaluate the integration of traditional spatial textures into contemporary use and the effect of interior design on user perception.

Qualitative research method was used within the scope of the research. Spatial Analysis was carried out with on-site observation, detection, photography and drawing techniques as data collection tools. Spatial analysis was structured from general to specific within the framework of the exterior-interior relationship of the coffee space; the space was evaluated based on spatial perception parameters (shape/form, proportion/size, material/texture, color, light/illumination, heat, sound and smell).

The findings revealed that users' spatial perceptions are directly related to the physical design components of the space. It was determined that interior design decisions, especially in concept spaces, play a decisive role on user satisfaction and preferences. The study draws attention to

the importance of structuring design decisions with a user-centered approach and provides data that can contribute to the field of interior design.

Keywords: Concept cafe spaces, interior design, perception, spatial perception parameters, Konya

KONSEPT KAFELERİN MEKÂNSAL ALGIYA ETKİSİ: DUDU FIRIN-KAHVE ÖRNEĞİ

ÖZET

Bu araştırma, kahve mekânlarının kullanıcı tercihleri üzerindeki etkilerini, mekânsal ve görsel algı bileşenleri bağlamında değerlendirmeyi amaçlamaktadır. Günümüzde kahve mekânları yalnızca bir tüketim alanı olmanın ötesinde; sosyalleşme, dinlenme, deneyim yaşama ve estetik tatmin gibi çok boyutlu işlevleriyle öne çıkan kamusal iç mekânlar hâline gelmiştir. Bu bağlamda, kullanıcıların bir mekâna ilişkin algısıyla iç mekân tasarımında kullanılan fiziksel unsurlar arasındaki ilişki, iç mimarlık disiplini açısından önemli bir araştırma alanı oluşturmaktadır. Bu çalışma, kullanıcıların görsel-mekânsal algılarını etkileyen fiziksel tasarım parametrelerinin, kullanıcı tercihleri üzerindeki etkisini incelemeye yöneliktir.

Araştırmanın uygulama alanı olarak, Konya ili Karatay ilçesinde yer alan "Dudu Fırın-Kahve" adlı kahve mekânı seçilmiştir. Mekân; Konya'nın tarihi çevresinde önemli bir noktada çevresiyle bütünlük kuran konumuyla kullanıcıya nostaljik ve estetik bir deneyim sunması açısından dikkat çekmektedir. Konya'nın tarihi merkezlerinden biri olan Bedesten çevresinde konumlanan bu yapı, geleneksel mimari unsurlarla çağdaş iç mekân düzenlemelerini bir araya getirerek hem kültürel mirası yaşatmakta hem de güncel bir sosyal buluşma noktası işlevi görmektedir. Bu bağlamda, Dudu Fırın mekânı; mekânsal algı ve kullanıcı tercihi ilişkisini değerlendirmek açısından özgün bir örnek teşkil etmektedir.

Çalışmada, mekânın fiziksel özelliklerinin –biçim, oran, doku, renk, ışık gibi parametrelerin– kullanıcı algısına nasıl yansıdığı analiz edilmiştir. Dudu Fırın'ın örneklem olarak seçilmesinde hem tarihi bağlamının sunduğu zenginlik hem de kullanıcılar arasındaki popülerliğinin yüksek olması etkili olmuştur. Bu yönüyle çalışma, geleneksel mekânsal dokuların çağdaş kullanıma entegrasyonu ile iç mekân tasarımının kullanıcı algısına etkisini birlikte değerlendirme fırsatı sunmaktadır.

Araştırma kapsamında nitel araştırma yöntemi kullanılmıştır. Veri toplama aracı olarak yerinde gözlem, tespit, fotoğraflama ve çizim teknikleriyle mekânsal Analiz gerçekleştirilmiştir. Mekânsal analiz, kahve mekânının dış-iç mekân ilişkisi çerçevesinde genelden özele doğru kurgulanmış; mekân, mekânsal algı parametreleri (biçim/form, oran/ölçü, malzeme/doku, renk, ışık/aydınlatma, ısı, ses ve koku) üzerinden değerlendirilmiştir.

Elde edilen bulgular, kullanıcıların mekânsal algılarının, mekânın fiziksel tasarım bileşenleriyle doğrudan ilişkili olduğunu ortaya koymuştur. Özellikle konsept mekânlarda iç mekân tasarım kararlarının, kullanıcı memnuniyeti ve tercihleri üzerinde belirleyici bir rol oynadığı saptanmıştır. Çalışma, tasarım kararlarının kullanıcı odaklı bir yaklaşımla yapılandırılmasının önemine dikkat çekmekte ve iç mekân tasarımı alanına katkı sunabilecek nitelikte veriler sağlamaktadır.

Anahtar Kelimeler: Konsept kafe Mekanları, iç mekan tasarımı, algı, mekânsal algı parametreleri, Konya.

ZAKAT AND WEALTH MEASURES IN ISLAMIC LAW

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ABSTRACT

Although the Quran provides definitive provisions on the obligation of zakat, it does not provide detailed information on who is obliged to pay zakat. Detailed information on the measure of wealth (nisab) is clarified through the hadiths and practices of the Prophet Muhammad. In the conditions of that day, who would be considered rich was determined in a way based on gold, silver and some other goods used as money. In the classical jurisprudence literature, the nisab of zakat is explained based on the practices of the Prophet Muhammad, based on gold, silver, animals and some land products. In the contemporary period, different ideas are expressed among Islamic jurists on how to determine the nisab of zakat, in addition to the classical understanding. This study focuses on the principles that should be valid in determining the measure of wealth in today's conditions. The criteria for wealth may vary in different economic and social conditions in Islamic societies and around the world. Within modern financial systems and global economic structures, the calculation and implementation of zakat may pose practical difficulties. However, the fundamental purpose of zakat remains the same: it should be used as a tool to strengthen the principles of social justice and solidarity in Islam and to maintain balance within society. Consequently, the importance of zakat and the criteria for wealth are among the fundamental elements that shape the social and economic order of Islam. Who is/should be considered rich may also change locally due to the social positions of the communities. From this point of view, it is not understood that the studies on who should be considered rich are important.

Keywords: Zakat, Nisab, Wealth.

İSLAM HUKUKUNDA ZEKÂT VE ZENGİNLİK ÖLÇÜLERİ

ÖZET

Kur'an zekâtı farziyyeti konusunda kesin hükümler ortaya koymakla birlikte, kimlerin zekât yükümlüsü olacağı hakkında ayrıntılı bilgi vermemektedir. Zenginliğin ölçüsü (nisab) ile ilgili ayrıntılı bilgi Hz. Peygamber'in hadisleri ve uygulamaları ile açıklık kazanmaktadır. O günün şartlarında para olarak kullanılan altın, gümüş ve diğer bir kısım mallar üzerinden kimlerin zengin sayılacağı bir şekilde belirlenmiştir. Klasik fıkıh literatüründe de Hz. Peygamber'in uygulamaları esas alınarak altın, gümüş, hayvanlar ve bir kısım toprak mahsulleri üzerinden zekâtın nisabı açıklanmaktadır. Çağdaş dönemde İslam hukukçuları arasında zekâtın nisabının nasıl belirleneceği konusunda klasik anlayışın yanında farklı düşünceler de dile getirilmektedir. Bu çalışma günümüz şartlarında zenginliğin ölçüsünü belirlenme konusunda hangi esasların geçerli olması gerektiği konusu üzerinde durmaktadır. Zenginlik kriterleri, İslam toplumlarında ve dünya genelinde farklı ekonomik ve sosyal koşullar altında değişiklik gösterebilir. Modern finansal sistemler ve küresel ekonomik yapılar içinde, zekâtın hesaplanması ve uygulanması pratik zorluklar doğurabilir. Ancak zekâtın temel amacı, İslam'ın sosyal adalet ve dayanışma ilkelerini güçlendirmek ve toplum içindeki dengeleri korumak için bir araç olarak kullanılması gerektiği gerçeği değişmez. Sonuç olarak, zekâtın önemi ve zenginlik kriterleri, İslam'ın sosyal ve ekonomik düzenini şekillendiren temel unsurlardan biridir. Kimlerin zengin olarak kabul edileceği/edilmesi gerektiği toplumluların sahip oldukları sosyal konumları gereği mahallî olarak ta değişebilmektedir. Bu noktadan hareketle kimlerin zengin olarak kabul edilmesi gerektiği konusundaki çalışmaların önemli olduğu anlaşılmamaktadır.

Anahtar Kelimeler: Zekât, Nisab, Zenginlik.

SUPPRESSIVE POTENTIAL OF ENTOMOPATHOGENIC NEMATODES (EPN) IN BIOLOGICAL CONTROL OF PEST SPECIES

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ABSTRACT

Nematodes from the families Steinernematidae and Heterorhabditidae have shown to be successful biocontrol agents against several insect pests. These little nematodes, in symbiotic relationship with bacteria (*Xenorhabdus* spp. in Steinernema, *Photorhabdus* spp. in Heterorhabditis), may rapidly infect and kill insects, hence offering an environmentally sustainable substitute for traditional pesticides. Emphasizing their biology, methods of action, and integration into integrated pest management (IPM) plans, this paper provides a thorough synthesis of entomopathogenic nematode (EPN) applications across several crops and pests. Key accomplishments—from the management of soil-dwelling larvae in orchards and field crops to the control of cryptic borers and greenhouse pests—are examined together with concerns including environmental sensitivity, formulation challenges, and inconsistent field performance. Particular focus is paid to studies and applications in Türkiye, where interest in EPNs for pest control is growing. Case studies from Turkish agricultural and international contexts show the value of EPN in both laboratory and field environments, stressing success factors and practical concerns for farmers and practitioners. Present results are summarized in the paper's conclusion along with future directions include increasing EPN heat/desiccation resistance, attaining affordable mass production, and strengthening their contribution to sustainable agriculture.

Keywords: Entomopathogenic nematodes; biological control; integrated pest management; Steinernema; Heterorhabditis; sustainable agriculture; Türkiye

ANTAGONISTIC FUNGI IN PLANT PARASITIC NEMATODE MANAGEMENT: SPECIES, APPLICATİON METHODS, AND FIELD EFFICACY IN VEGETABLES

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ABSTRACT

Plant-parasitic nematodes (PPNs) can cause a significant concealed threat in agriculture, especially in vegetable production, where their pervasive infestation results in annual global crop losses surpassing $157 billion, inflicting substantial economic strain on agricultural systems and food security. Therefore, the application of efficient nematode management strategies—such as cultural, chemical, biological, and integrated methods—is crucial to reduce yield losses. Among these control strategies, antagonistic fungi have emerged as a viable biological control option due to their capacity to parasitize nematode eggs, degrade cuticles, and interrupt worm life cycles, providing an eco-friendly alternative to synthetic nematicides. Both, fungi and nematodes are among the most abundant and ubiquitous organisms inhabit the same soil environment, it is inevitable that they will engage in various forms of interaction. It is widely known that fungi synthesize antibiotic metabolites and produce certain compounds that have antagonistic effects on nematodes and other organisms. Furthermore, plant-parasitic nematodes (PPN) are estimated to cause over $157 billion in crop losses annually, resulting in significant economic losses in agriculture. This situation suggests that fungi with antagonistic relationships against nematodes could be used as biological control agents. Because due to chemical nematicides elevate potential health risks and environmental concerns they may generate they have been subjected to restrictions by authorities in recent times. This study provides an in-depth analysis of the diversity of nematophagous fungi and their efficacy in applied contexts, emphasizing the following four groups: nematode-trapping fungi, endoparasitic fungi, egg-parasitic fungi, and toxin-producing fungi. Thus, it highlights the significance of antagonistic fungi such as *Pochonia chlamydosporia*, *Purpureocillium lilacinum*, *Trichoderma* spp., *Arthrobotrys oligospora*, and *Muscodor albus*. In application, the evaluation of technologies, solid substrate and liquid fermentation product formulations, seed treatment, and converter distribution systems are utilized.Various cultivation systems, regional studies, fungal strain selection, formulation selection, soil conditions, cultivation types, and other integrated management practices have demonstrated control efficiency rates ranging from 30% to 85%.

Keywords: antagonistic fungus, *P. Chlamydosporia*, biological control, nematophagous fungus, formulation technology

TECHNICAL SPECIFICATIONS OF PRISMATIC BALERS

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ABSTRACT

The use of bales and the mechanization of the production chain are important issues in the agricultural sector. Processing and transporting bales is a tiring and difficult task for farmers. Storing bales is a time-consuming process due to low manpower requirements. In the past, agricultural crops such as wheat were turned into straw in sizes that animals could eat with a more primitive machine called a thresher. Straw is animal food that takes up a lot of space like fluffy dust. Therefore, more storage space was needed. In order to store more straw in smaller areas, it is important to pack straw produced from crops such as wheat, barley, clover, and vetch. Balers have an important place in agriculture for more efficient use of closed areas. Balers are machines used to compress straw and other materials in different ways. Of these compression types, prismatic balers are the most commonly used baler. Prismatic balers transfer the crop to the collection unit-feeding unit-pressing room-tying unit and discharge unit in order and complete the baling process. In this study, the stages of the crop until baling and the technical features of the prismatic balers are discussed. These machines are usually pulled from the side of the tractor and driven by the tractor's power transmission box (PTO). These balers are machines that cover a large area in the field. These balers cut the stem part of the harvested and spread crop into smaller pieces so that animals can consume it more easily. In this way, it increases the compressibility rate of the crop and allows more stock to be made in a smaller area. In addition, bales of the desired size and dimensions can be produced from these small crops and used in different animal husbandry. Savings in time and labor costs can be achieved when preparing feed with the produced bales. It is thought that the bales will increase the storage capacity of processed agricultural crop waste and provide farmers with more long-term flexibility in animal nutrition.

Keywords: Prismatic baler machines, baling, agricultural machinery

PRİZMATİK BALYA MAKİNELERİNİN TEKNİK ÖZELLİKLERİ

ÖZET

Balyaların kullanımı, üretim zincirinin makineleşmesi tarım sektöründe önemli bir konudur. Balyaların işlenmesi ve taşınması çiftçiler açısından yorucu ve zor bir güç gerektiren bir iştir. Balyalar depolanmaları düşük insan gücü gereksinimleri nedeniyle vakit alan işlemlerdir. Eski zamanlarda daha ilkel bir makine olan Patoz ile buğday gibi tarımsal mahsuller hayvanların yiyebileceği büyüklüklerdeki saman haline getirilmekteydi. Saman kabarık toz gibi çok yer kaplayan hayvan yiyeceğidir. Dolayısı ile daha fazla depolama alanına gereksinim duyulmaktaydı. Daha küçük alanlara daha fazla samanın depolanabilmesi için buğday, arpa, yonca, fiğ gibi mahsullerden üretilen samanın paketlenmesi önem arz etmektedir. Kapalı alanların daha verimli kullanılabilmesi için tarımda balya makineleri önemli yere sahiptir. Balya makineleri, saman ve diğer malzemeleri değişik şekillerde sıkıştırmak için kullanılan makinalardır. Bu sıkıştırma şekillerinden prizmatik balya makineleri en yaygın kullanılan balya makinesidir. Prizmatik balya makineleri mahsulü sırasıyla toplama ünitesi-besleme ünitesi-pres odası-bağlama ünitesi ve boşaltma ünitesine sıralamasıyla aktararak balyalama işlemini tamamlar. Bu çalışmada mahsulün balyalama olana kadar ki aşamaları ve prizmatik balya makinelerinin teknik özellikleri ele alınmıştır. Bu makinalar genellikle traktörün yan tarafından çekilir ve traktörün güç aktarma kutusundan (PTO) tahrik edilir. Bu balya makinaları tarlada geniş bir alanı kaplayan makinalardır. Bu balye makineleri hasat edilen ve tarlaya yayılan mahsulün sap kısmını daha küçük parçalara keserek hayvanların daha kolay tüketmesini sağlamaktadır. Bu sayede mahsulün sıkıştırılabilirlik oranını artırarak daha küçük alana daha fazla stok yapılabilmesini sağlamaktadır. Bunun yanısıra üretilen bu küçük parça mahsüllerden istenilen boyut ve büyüklükte balyalar üretilerek değişik hayvan besiciliğinde kullanılması sağlanabilmektedir. Üretilen balyalar ile yem hazırlanırken zamandan ve işçilik maliyetlerinden tasarruf sağlanabilmektedir. Balyalar işlenmiş tarımsal mahsül atıklarının depolama kapasitesini artırarak çiftçilere hayvan beslenmesinde daha fazla uzun vadeli esneklik sağlayacağını düşünülmektedir.

Anahtar Kelimeler: Prizmatik balya makineleri, balyalama, tarım makineleri

THE IMPORTANCE OF UTILIZATION OF BLACKTHORN (*Prunus spinosa* L.) WASTE SEEDS BY DIFFERENT EXTRACTION METHODS

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ABSTRACT

Prunus spinosa L., usually known as Jackal or Blackthorn plum, is widely distributed in Europe, Western Asia and Northwest Africa at altitudes of 0-1700 m. The fruit is commonly consumed raw and processed into jelly, marmalade, jam and compote. Blackthorn fruits extracts are available in various areas including food industry as colorants and preservatives due to antioxidant and antibacterial properties of polyphenols. For example, the color, adhesive structure, appearance and general acceptability of fruits improves the symptoms of freezing. Berries are considered an excellent source of vitamin C. Blackthorn fruit is mostly used for its health benefits such as laxative, hemostatic, de-worming and constipating. Blackthorn fruits are also rich in bioactive compounds, including minerals, amino acids, vitamins, triterpenes, phytosterols, phenolic and organic acids. Phytochemicals, especially those with high antioxidant activity, appear to reduce the risk of chronic diseases such as cardiovascular disorders and cancer. In Blackthorn seed oil obtained by cold pressing method in Blackthorn, where different extraction methods were applied, vanillin was determined as the most important phenolic component, while oleic acid was found at the highest rate. β-sitosterols are found at high levels. Oleic acid constitutes the main fatty acid in hexane-formed seed extracts. Blackthorn seeds, which are traditionally discarded, are seen to have various bioactive images in the extract obtained by supercritical CO_2 extraction method. These result show that *P. spinosa* seed extracts have potential pharmaceutical and nutraceutical applications. The fruit parts of the Blackthorn plum, which are generally, are used. The seed parts remain as waste. Therefore, in this study, there are studies in which the recovery of the remaining seeds is provided by different extraction methods and the bioactive compounds in the obtained extracts are determined.

Keywords: *Prunus spinosa L.*, Extraction methods, Waste seeds, Bioactive compounds.

SUSTAINABLE MARINE TOURISM: THE CASE OF BURHANİYE

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ABSTRACT

The United Nations World Tourism Organization (UNWTO) defines sustainable tourism as "tourism that fully considers current and future economic, social and environmental impacts and meets the needs of the industry, the environment, visitors and host communities". The concept of sustainable is of vital importance as it protects long-term economic, environmental and social life. Marine tourism includes activities such as water sports, yacht and boat trips, etc. and related hospitality services. It is envisaged to create stable local development by promoting resource efficiency and environmental sustainability in this type of tourism, which is highly integrated with other types of tourism.

With its 8333 km. long coastline with a rich history and favorable climatic conditions, Turkey has a significant potential for sea tourism on both the Mediterranean and Aegean coasts. With its seas that can experience four seasons at the same time and maintain their warmth even in winter, it is a geologically very suitable country for sea tourism. The importance of the subject emerges with this potential. It is aimed evaluate the sea tourism potential of Burhaniye District of Balıkesir, located in the Edremit Gulf of our country, which has a sea tourism potential, in terms of alternative tourism and to extend the short season to the whole year. It is also important to direct young people to marine tourism activities. In addition, it will be emphasized on what needs to be done in terms of ensuring sustainability by revealing the problems, especially the pollution factor, which is one of the factors that pose a threat to the tourism in question. In this research, qualitative research method will be used, and document analysis will be made from secondary data. Document analysis will be created by scanning written sources such as newspapers, magazines, books, reports, articles and theses.

Keywords: Sustainable Tourism, Sea Tourism, Balıkesir, Burhaniye.

SÜRDÜRÜLEBİLİR DENİZ TURİZMİ: BURHANİYE ÖRNEĞİ

ÖZET

Birleşmiş Milletler Dünya Turizm Örgütü (UNWTO) sürdürülebilir turizmi "mevcut ve gelecekteki ekonomik, sosyal, çevresel etkileri tam olarak göz önüne alan; endüstrinin, çevrenin, ziyaret edenlerin ve ev sahibi toplumların ihtiyaçlarını karşılayan turizm çeşidi" olarak tanımlamıştır. Sürdürülebilir kavramı uzun vadeli ekonomik, çevresel, sosyal hayatı koruma altına aldığı için hayati öneme sahiptir. Deniz turizmi ise, su sporları,yat ve tekne gezileri vb. gibi faaliyetleri ve bunlara bağlı ağırlama hizmetlerini içermektedir. Diğer turizm çeşitleriyle entekrasyonu yüksek olan sözkonusu turizm çeşidinde kaynak verimliliğinin ve çevrenin sürdürülebilirliğinin teşvik edilerek istikrarlı yerel kalkınmanın oluşturulması öngörülmektedir.

Türkiye 8333 km. uzunluğunda zengin tarihi barındıran kıyıları ve kuygun iklim koşulları ile hem Akdeniz hem de Ege sahillerinde deniz turizmi açısından önemli potansiyele sahiptir. Aynı anda dört mevsimi yaşayabilen ve kışın dahi sıcaklığını koruyan denizleri ile, jeolojik açıdan deniz turizmine çok uygun bir ülkedir. Konunun önemi de bu potansiyel ile ortaya çıkmaktadır. Deniz turizm potansiyeline sahip ülkemizin Edremit Körfezinde yer alan Balıkesir'in Burhaniye İlçesi'nin alternatif turizm açısından deniz turizm potansiyelinin değerlendirilerek kısa sezonun bütün yıla yayılmasının sağlanması amaçlanmaktadır. Ayrıca deniz turizm etkinliklerine gençlerin yönlendirilmesi de önem arz etmektedir. Bunun yanında sözkonusu turizm açısından tehdit unsuru oluşturan faktörlerden kirlilik unsuru başta olmak üzere sorunların ortaya konularak sürüdürlebilirliğin sağlanması açısından yapılması gerekenler üzerinde durulacaktır. Bu araştırmada nitel araştırma yöntemi kullanılarak ikincil verilerden doküman analizi yapılacaktır. Doküman analizi geçmişe dönük gazete, dergi, kitap, rapor, makale ve tez gibi yazılı kaynaklar taranmasıyla oluşturulacaktır.

Anahtar Kelimeler: Sürdürülebilir Turizm, Deniz Turizmi, Balıkesir, Burhaniye.

CULTURAL TOURISM POTENTIAL OF SAVAŞTEPE SARIBEYLER

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ABSTRACT

Culture is a set of tangible and intangible values that distinguishes a society from other societies, continues to change from past to present, gives an identity with its unique art, beliefs, customs, traditions, understanding and behaviors, and provides order by giving a sense of solidarity and unity. Cultural tourism is a type of tourism in which foreigners travel to experience cultural places, activities and artifacts in a region by seeing them on site. This tourism is also important as a type of tourism that develops conservation awareness and provides national and local economic gain

Located in the North Aegean, Balıkesir province is one of the prominent provinces in cultural tourism with its cultural heritage, historical artifacts, museums and ruins. The ancient cities of Antandros (Edremit-Altınoluk), Daskyleion (Bandırma-Ergili), Kyzikos (Erdek) have important historical heritage in terms of cultural tourism. However, despite its potential, Balıkesir cannot create economic, social and cultural value by highlighting its cultural heritage in tourism except for certain settlements. The aim of this study is to draw attention to the issue by revealing the tourism potential of Sarıbeyler Neighborhood in Savaştepe District of Balıkesir Province. Thus, it is envisaged to encourage the initiation of studies to contribute to the national economy with sustainable, four-season tourism income by bringing new tourism routes to the province and the region. The settlement in question is located in the North Aegean, which has hosted the oldest civilizations and has rich traditional values in terms of food culture and handicrafts. The subject is important in terms of evaluating the cultural richness of Sarıbeyler Neighborhood as tourism application areas, revealing new touristic products and transforming them into income-generating elements. In the study, archive/document scanning, one of the qualitative research methods, will be carried out and awareness will be raised by photographing the values on site, transforming them into visuals and writing these values down.

Keywords: Cultural Tourism, , Balıkesir, Savaştepe, Sarıbeyler.

SAVAŞTEPE SARIBEYLER'İN KÜLTÜR TURİZM POTANSİYELİ

ÖZET

Kültür, bir toplumu diğer toplumlardan ayıran, geçmişten günümüze değişerek devam eden, kendine özgü, sanatı, inançları, örf ve adetleri, anlayış ve davranışları ile bir kimlik kazandıran, dayanışma ve birlik duygusu vererek düzeni de sağlayan maddi ve manevi değerlerin bütünüdür. Kültür turizmi, yer yabancılarının bir yöredeki kültürel mekanları,etkinlikleri ve eserleri yerinde görerek deneyimlemek için seyahat ettiği bir turizm türüdür. Bu turizm aynı zamanda koruma bilincini geliştiren, ülkesel ve yerel ekonomik kazanç sağlayan bir turizm çeşidi olarak önem arz etmektedir.

Kuzey Ege'de bulunan Balıkesir ili sahip olduğu kültürel mirası, tarihi eserleri, müzeleri, Ören yerleri ile kültür turizminde öne çıkan illerden biridir. Antandros (Edremit-Altınoluk), Daskyleion (Bandırma-Ergili), Kyzikos (Erdek) antik kentleri bölgenin kültür turizmi açısından önemli tarihi mirasa sahiptir. Ancak sahip olduğu potansiyeline rağmen Balıkesir kültürel mirasını turizmde belli yerleşim yerleri dışında öne çıkararak, ekonomik, sosyal ve kültürel değer yaratamamaktadır. Bu çalışmanın amacı Balıkesir İli Savaştepe İlçesi, Sarıbeyler Mahallesi'nin kültür turizm potansiyelini ortaya koyarak konuya dikkat çekmektir. Böylece yeni turizm rotalarının il ve bölgeye kazandırılmasıyla sürdürülebilir, dört mevsim turizm geliri ile ülke ekonomisine katkı sağlamak için çalışmaların başlatılmasını teşvik etmek öngörülmektedir. Sözkonusu yerleşim yeri en eski medeniyetlere ev sahipliği yapmış, beslenme kültürü ve el sanatları açısından zengin geleneksel değerlere sahip Kuzey Ege'de yer almaktadır. Sarıbeyler Mahallesi'nin sahip olduğu kültürel zenginliklerin turizm uygulama alanları olarak değerlendirilmesi, yeni turistik ürünlerin ortaya çıkarılması ve gelir getirici unsurlara dönüştürülmesi açısından konu önem arz etmektedir. Çalışmada nitel araştırma yöntemlerinden arşiv/doküman taraması yapılacak ve yerinde değerlerin fotoğraflanması görsele dönüştürülmesi ve bu değerlerin yazılı hale getirilmesi yöntemiyle farkındalık artırılacaktır.

Anahtar Kelimeler: Kültür Turizmi, , Balıkesir Savaştepe, Sarıbeyler.

EXPLORING GENDER DIFFERENCES IN RISK BEHAVIOUR AND PROFIT MARGINS OF ORANGE FLESH SWEET POTATO PRODUCERS IN OSUN STATE, NIGERIA

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ABSTRACT

Orange Flesh Sweet Potato (OFSP) has emerged as a vital biofortified crop contributing to food and nutrition security in Nigeria, yet its production faces significant risks that threaten farmer profitability. Despite Nigeria being among the top producers of sweet potatoes in Africa, smallholder farmers, particularly in Osun State, continue to grapple with production and market uncertainties. This study explored the gender dimensions of risk behaviour and profitability among OFSP farmers in Osun State, Nigeria. A total of 100 farmers were randomly selected, and data were collected using structured questionnaires. Analytical tools applied included descriptive statistics, the Safety-First Model, gross margin analysis, and independent t-test.

Findings revealed that key sources of production risk included pest and disease infestation (95.0%), limited access to quality planting materials (87.0%), high cost of inputs (84.0%), and price volatility (75.0%). Gender analysis of risk attitudes indicated that 68% of male farmers and 78% of female farmers were risk-averse. Profitability assessment showed that male farmers earned an average gross margin of ₦218,195.80 per hectare, which was significantly higher ($p<0.01$) than the ₦192,916.40 recorded by female farmers.

The study recommends that relevant agricultural agencies and research institutions ensure timely access to improved OFSP vines while enhancing extension services to build farmers' capacity in risk management and productivity improvement. These interventions are crucial for narrowing gender gaps in profitability and strengthening the resilience of OFSP farming systems.

Keywords: Profitability, Risk Behaviour, Gender, Orange Flesh Sweet Potato, Smallholder Farmers, Nigeria

CRANIO-CAUDAL GRADIENT IN THE DISTRIBUTION OF MICROBIOTA OF THE GASTROINTESTINAL TRACT OF SHEEP

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ABSTRACT

The sheep gastrointestinal tract is a complex ecosystem that hosts a huge diversity of microorganisms that play a critical role in digestion, immune defense, and overall health of the animal. The distribution of these microorganisms is heterogeneous and shows a pronounced cranio-caudal gradient. Using metabarcoding techniques, the features of the cranio-caudal gradient of microorganism distribution along the gastrointestinal tract of Romanov lambs were determined. The rumen of sheep, where the main fermentation of plant fibers occurs, is usually dominated by anaerobic bacteria such as *Fibrobacter succinogenes*, *Ruminococcus albus*, and *Ruminococcus flavefaciens*, as well as methanogenic archaea such as *Methanobrevibacter*. They break down cellulose, hemicellulose, and starch into volatile fatty acids (VFA), which serve as the main source of energy for sheep. Bacteria of the genus *Ruminococcus* were also one of the dominant genera in the rumen (upper part), their share was 19%. But the most abundant genus was bacteria of the genus *SFMI01* (25%). Also among the dominant OTUs were bacteria of the family *Lachnospiraceae* (11%), genera *Limivicinus* (6%) and *Nanosyncoccus* (5%). As they move into the abomasum, the acidic environment suppresses the growth of many rumen bacteria, and acid-resistant species such as *Lactobacillus* and *Streptococcus* begin to dominate. Also, in Romanov lambs, the microbiocenosis of the lower part of the rumen turned out to be the most isolated in terms of the composition of microbes, where bacteria of the genus *Latilactobacillus* dominated (75%). The microbiota of the upper, middle and lower part of the cecum differed insignificantly. The dominant genera were Nanosyncoccus (its share was 18, 17 and 14%). *Faecousia* (10, 9 and 11%), *Lachnospiraceae* families (7, 7 and 6%), *Ruminococcus* (2% each). In the large intestine, where water absorption and feces formation occur, the microbiota undergoes changes again. The proportion of bacteria capable of fermenting undigested carbohydrates and proteins increases, including *Bacteroides* and *Prevotella*. The cranio-caudal gradient reflects the adaptation of the microbiota to different environmental conditions and functions of each section of the gastrointestinal tract, ensuring optimal digestion and assimilation of nutrients by the sheep.

Keywords: метабаркодинг, микробиоценоз, рубец, слепая кишка, кал, ягнята.

OPPORTUNITIES IN BREEDING AND SEED PRODUCTION OF KOI CARP AND GOLDFISH: A COMPARATIVE STUDY

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ABSTRACT

The ornamental fish industry presents significant economic potential, especially in the international market, where demand for high-quality fish seed continues to grow. This study explores the breeding and seed production techniques of two widely cultivated ornamental fish species—Koi carp (Cyprinus rubrofuscus) and goldfish (Carassius auratus). Both species follow a similar induced breeding protocol, wherein synthetic hormones are administered at doses of 0.3 ml/kg body weight for males and 0.6 ml/kg for females. Post hormone administration, the brooders are released into controlled breeding tanks with regulated temperature and water flow conditions. Following successful spawning, a 2–3 day period without feeding is maintained to optimize hatchling survival. Subsequently, formulated feeds are introduced. This paper also includes an economic analysis of the breeding process, demonstrating the viability and profitability of ornamental fish seed production. The findings support scalable breeding practices to meet global market demand.

Keywords: Ornamental fish, Induced breeding, Koi carp, Goldfish, Seed production

ISOLATION OF POLYPHENOLS FROM JACKFRUIT PULP AND THEIR INCORPORATION INTO CHITOSAN-BASED EDIBLE FILMS WITH ANTIOXIDANT PROPERTIES

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ABSTRACT

The present study investigates the extraction of polyphenolic compounds from Artocarpus heterophyllus (jackfruit) pulp and explores their potential as bioactive agents in the development of functional edible films. Polyphenols are known for their antioxidant activity and potential applications in enhancing food preservation and extending shelf life when incorporated into biodegradable packaging materials. Jackfruit pulp, a rich yet underutilized source of natural antioxidants, was selected for polyphenol extraction using an ethanol-based solvent system. The extracted compounds were subjected to a range of antioxidant assays, including Total Antioxidant Activity (TAA), Total Phenolic Content (TPC), Total Flavonoid Content (TFC), 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, and Ferric Reducing Antioxidant Power (FRAP). Additionally, a proximate analysis of the jackfruit pulp was performed to determine its nutritional composition including moisture, ash, protein, fat, and carbohydrate content.Following biochemical characterization, the extracted polyphenols were incorporated into chitosan-based edible films at varying concentrations (2.5%, 5%, and 7.5%) to assess their impact on the functional and antioxidant properties of the films. The resulting films were evaluated using the same antioxidant assays to determine the stability and effectiveness of polyphenol integration within the film matrix. Results indicated a concentration-dependent enhancement in antioxidant activity across all tests, confirming the successful retention of bioactivity in the film formulations. Notably, films with higher polyphenol concentrations demonstrated significantly greater radical scavenging capacity and reducing power.This study highlights the dual benefit of utilizing a fruit waste byproduct and enhancing the functional quality of biodegradable films, presenting a sustainable and natural alternative for food packaging applications. The findings provide promising insights into the use of jackfruit-derived bioactives in the formulation of active packaging materials aimed at improving food safety and shelf life.

Keywords: · Polyphenol extraction, Jackfruit pulp, Antioxidant activity, Chitosan-based edible film, Biodegradable packaging, Functional food applications

DEVELOPMENT OF BROCCOLI-INFUSED BARNYARD MILLET PASTA

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ABSTRACT

The increasing demand for functional and health-oriented foods has driven innovation in pasta development using alternative grains and nutrient-rich vegetables. In this study, pasta was formulated using a 1:1 blend of barnyard millet flour and refined wheat flour, enriched with broccoli powder at four levels: 0%, 2.5%, 5%, and 10%. Barnyard millet, a gluten-free pseudocereal, is known for its high fiber, low glycemic index, and micronutrient richness, while refined wheat flour contributes to dough structure and texture. Broccoli powder, rich in antioxidants, dietary fiber, and phytochemicals, was incorporated to enhance the nutritional and functional properties of the pasta.

Proximate analysis showed a steady increase in protein content with broccoli addition, from 10.24 g in the control to 12.37 g at 10% incorporation. Ash content, indicative of mineral enrichment, also rose progressively with higher broccoli levels. Colorimetric measurements revealed a decline in lightness (L*) values from 78.99 to 75.61 and a shift in a* values from 2.49 to 0.39, indicating a greener hue. The b* values increased from 13.86 to 18.15, reflecting enhanced yellowness, particularly at higher broccoli concentrations.

Farinograph analysis of the base flour (barnyard millet and refined wheat) showed a water absorption of 53.7 mL, which increased to 58.5 mL with 5% broccoli incorporation, suggesting improved water-holding capacity due to fiber and protein interactions. Sensory evaluation revealed that pasta with 2.5% and 5% broccoli powder achieved the highest consumer acceptance, particularly in terms of flavor, texture, and appearance. Although the 10% sample exhibited superior nutritional qualities, it was less favored due to stronger vegetal flavor and darker coloration.

Overall, the 5% broccoli-enriched pasta offered an optimal balance between enhanced nutrition and sensory appeal, making it a promising functional product for health-conscious consumers seeking nutrient-dense, plant-based pasta alternatives.

Keywords: Broccoli powder; Pasta; Texture; Protein; Sensory Studies

GENETIC ANALYSIS OF COMPLEMENT COMPONENT 5 GENE IN MASTITIC COWS

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ABSTRACT

Pakistan is ranked fourth in milk production worldwide, after India, China, and the United States. Indigenous cattle breeds are well-known breeds for milk production globally. These breeds experiences a number of diseases such as mastitis, theileriosis, anaplasmosis, babesiosis, foot and mouth disease and lumpy skin disease. Mastitis, or inflammation of the mammary gland, is one of the most prevalent diseases that is classified by the mammary gland's inflammatory reaction. Clinical and subclinical mastitis not only lowers milk production but also lowers the nutritional content of milk, which leads to significant financial losses. Worldwide, the dairy industry suffers large and regular financial losses as a result of mastitis. This financial stress is brought on by the increased costs of treating mastitis as well as losses from a variety of problems, such as decreased milk production, rejected milk, and culling. *S. aureus* is the most significant pathogens, responsible for clinical and subclinical mastitis in all over the world. The current study was designed to sequence and analysis of the partial C5 gene in to identify single nucleotide polymorphism and to find out the association analysis of C5 gene as an indicator of mastitis in dairy animals. Sequence analysis of C5 gene aid as a molecular marker for mastitis resistance and subsequently to be used in a selection of dairy animals.

Keywords: Milk, Mastitis, cow, Milk, gene

QUALITATIVE PHYTOCHEMICAL ANALYSIS OF THE FRESH AND PROCESSED *CAPSICUM ANNUM* (PEPPER) AND *SOLANUM LYCOPERSICUM* (TOMATO) USING ETHANOLIC EXTRACTS

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ABSTRACT

Phytochemical is a collective term for plant chemicals with varied structure and function. Solanum lycopersicum (Tomato) and Capsicum annum (Pepper) are the world's most highly consumed vegetables due to their status as basic ingredients in many raw, cooked or processed foods. The extracts for fresh and processed tomato and pepper were prepared using ethanol as solvent they were analyzed for various phytochemicals (alkaloids, flavonoids, saponins, steroids, phenolics, and tannins). The result revealed that the processing method slightly affects the presence of the phytochemical in both tomatoes and peppers. Alkaloids were absent in the processed tomato and pepper but flavonoids, saponins, steroids, phenolics, and tannins were all present in both the extracts. Based on this study both fresh and processed tomatoes and peppers can still provide essential phytochemicals associated with health benefits. However, the potential loss of alkaloids in processed form may be attributed to the use of high temperatures during the drying method. This signifies that fresh vegetables have more nutritional health benefits than processed ones but all can be consumed because most of these compounds contribute to the desired nutritional or therapeutic properties of food products.

Keywords: *Phytocheimcal, Solanum lycopersicum, Capsicum annum, Vegetables, Extracts.*

GRAFTING COMPATIBILITY AND MORPHOLOGICAL PERFORMANCE OF *Cupressus arizonica* AND *Calocedrus decurrens* ON *Cupressus sempervirens* UNDER MEDITERRANEAN CONDITIONS

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ABSTRACT

Grafting is an important technique for the clonal propagation of ornamental conifers, particularly for species that have low rooting potential when using conventional cutting methods. This study evaluates the grafting compatibility, physiological integration, and post-grafting morphological performance of two conifer species: Cupressus arizonica and Calocedrus decurrens 'Aureovariegata, grafted onto a widely available Mediterranean rootstock, Cupressus sempervirens. Conducted in a controlled greenhouse environment, the experiment aimed to assess the biological viability and morphological outcomes of both intra- and intergeneric grafting combinations within the Cupressaceae family.

The results indicated a high grafting success rate of 87% for the C. arizonica/C. Sempervirens combination, demonstrating vigorous and uniform vegetative growth. This suggests strong physiological and taxonomic compatibility within the genus Cupressus. In contrast, the C. decurrens grafts had a success rate of 82%. Still, they showed signs of anatomical mismatch, including asynchronous growth patterns and stress indicators in the rootstock, reflecting limited intergeneric compatibility.

Quantitative assessments of plant height, leaf area, and biomass accumulation, along with relative growth rate (RGR) analyses, highlighted significant differences in growth dynamics between the two scion/rootstock combinations. The study includes graphical comparisons of RGR and shoot biomass accumulation to illustrate these differences.

These findings emphasize the importance of taxonomic proximity for achieving successful vascular integration and long-term physiological stability in grafting. The research contributes valuable knowledge to optimize vegetative propagation strategies for Mediterranean ornamental nurseries. Furthermore, it supports broader efforts to diversify the range of drought-tolerant coniferous species in the context of climate adaptation and sustainable landscape horticulture.

Keywords: vegetative propagation, graft compatibility, conifers, ornamental species, Cupressus, Calocedrus, Mediterranean climate.

EXPLORING THE DIGITAL LITERACY PROFICIENCY OF RURAL YOUTHS IN ONA-ARA LOCAL GOVERNMENT AREA, OYO STATE

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ABSTRACT

Digital literacy has become an essential competency in the modern world and it has the potential to equip youths' with necessary skills to navigate the digital world effectively, give access to better information and improve rural development. This study examined the level of digital literacy among rural youths in Ona-Ara Local Government Area, Oyo State, Nigeria. A multistage sampling technique was used in selecting the 120 respondents from Akanran, Gbedun and Araromi. A structured questionnaire was used to collect primary data on respondents' personal characteristics; ownership of digital devices; perception towards digital literacy; factors influencing digital literacy and level of digital literacy skills. For the analysis of the data collected, descriptive statistics (frequency, percentage and mean) and inferential (Chi-square and PPMC) were used. The result of the study revealed that majority of the respondents were female (50.8%), christians (49.2%), artisans (61.7%), had secondary education (65.0%). About (40.8%) of the respondents belonged to the age group of 18 to 22 years with a mean age of 25.48 ±5.60 years and majority (78.3%) owned smartphone. A significant proportion of them possess basic digital literacy skills and their proficiency in advanced digital tasks such as content creation, online research, and coding remains limited. The key factors influencing digital literacy were cost of devices maintenance (0.97), financial limitations (0.95) and ability to purchase a digital device (0.94). Additionally, challenges such as the high cost of digital devices (1.58), inability to afford internet subscription (1.40) and limited access to stable internet (1.10) significantly hinder digital literacy development. Despite these constraints, 56.7% had favorable perception towards digital literacy and the level of digital literacy (53.3%) among respondents was high. There was a significant relationship between respondents' age ($r = -0.361$, $p < 0.001$), years of formal education ($r = 0.471$, $p < 0.001$) and their level of digital literacy. Also, there is significant relationship between digital device ownership and digital literacy levels among the respondents. Based on these findings, the study concludes that level of literacy is slightly high. It is recommended that targeted interventions, including improved digital infrastructure, affordable digital device programs, and collaboration between the government, private sector, and non-governmental organizations (NGOs) to fund digital initiatives in rural areas for rural youths

EVALUATION OF GROWTH PARAMETERS AND ANTIOXIDANT DEFENSE MECHANISMS ON MUNG BEAN (*Vigna radiata* (L.) Wilczek) UNDER ARSENIC STRESS

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ABSTRACT

The present study investigated the effect of arsenic stress on mung bean (Vigna radiate (L.) R. Wilczek) through various morpho-physiological and antioxidant defense mechanisms. In mung beans, arsenic leads to a reduction in seed germination and growth, resulting in decreased productivity. Mung bean plants were exposed to different concentrations of arsenic (10, 25, and 50µM) for various durations followed by a recovery period. Various parameters such as root and shoot lengths, fresh and dry weight, chlorophyll content, membrane stability index, relative electrical conductivity, relative water content, and chlorophyll levels were evaluated. Additionally, biochemical parameters including malondialdehyde (MDA) and superoxide dismutase (SOD) activity were assessed. The experiments were conducted in a randomized block design with three replicates each. The results showed an increase in superoxide dismutase (SOD) activity in the plants with higher concentrations of arsenic, indicating their response to arsenic stress. Conversely, lipid peroxidation, a measure of cellular damage, decreased as arsenic concentration increased. This suggests that mung bean plants exhibited higher SOD enzyme activity at higher arsenic concentrations (50µM) and lower activity at lower concentrations (10µM). Membranes were found to be protected and stable at lower arsenic concentrations, but became increasingly unstable and damaged at higher concentrations. The total stress response index (TSRI), calculated based on combined morpho-physiological and biochemical parameters, revealed that mung bean plants were most affected by the highest arsenic concentration (50µM), while they were able to tolerate the lower concentration of 10µM. These findings provide valuable insights into the tolerance mechanisms employed by mung bean plants in response to arsenic stress and can contribute to the development of strategies for improving crop resilience under arsenic stress conditions.

Keywords: Vigna radiata (L.) R. Wilczek), NaAsO2- Sodium Arsenite, TSRI- Total stress, responsive index.

CHARACTERIZATION OF FUNGAL AGENTS RESPONSIBLE FOR THE LEAF DECLINE OF OLIVE TREES IN THE ORIENTAL REGION OF MOROCCO

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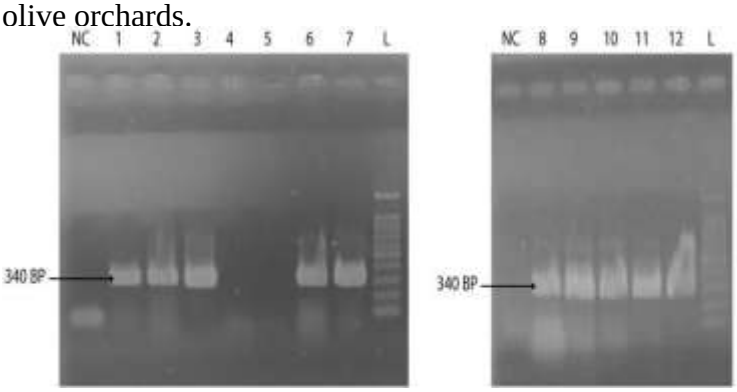
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ABSTRACT

In the eastern region of Morocco, symptoms of decline and necrosis were observed on olive trees (*Olea europaea*) in several farms. Fungal isolates were obtained from infected leaves and shoots. Pathogen identification was conducted through a dual approach: morphological examination of conidia under a microscope and molecular detection via PCR amplification using specific primers AAF2 and AAR3, which confirmed the presence of *Alternaria alternata.* Pathogenicity tests were performed on healthy olive plants, and the observed symptoms were successfully reproduced, fulfilling Koch's postulates. This study represents the first report of *A. alternata* as the causal agent of olive tree decline in the eastern region of Morocco, highlighting the importance of early diagnosis and management of this emerging pathogen in olive orchards.



PROTEINS LINKED TO COLON CANCER: SYSTEMATIC REVIEW

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ABSTRACT

Colorectal cancer (CRC) is a leading global health threat, with approximately 2 million new cases and 1 million deaths reported. In 2018, making it the 3rd leading cause of cancer deaths among men and 2nd among women. Beta-caryophyllene (BCP) is a naturally occurring bicyclic sesquiterpene found in various plants, including black pepper and cannabis. It has acquired attention for its potential therapeutic effects, particularly its anti-inflammatory and anticancer properties. Recent studies suggest that BCP may play a significant role in the prevention and treatment of colon cancer, a leading cause of cancer-related deaths worldwide. BCP utilize its effects through its interaction with the cannabinoid receptor type 2 (CB2), triggering anti-inflammatory pathways and promoting apoptosis in cancer cells. Furthermore, BCP has been shown to inhibit cancer cell proliferation, metastasis, and angiogenesis, all key factors in the progression of colon cancer. This review explores the molecular mechanisms underlying BCP's potential antitumor activity in colon cancer, highlighting its ability to modulate signaling pathways such as NF-κB, VEGF, Caspases, BCL-2 and MAPK. Additionally, the safety profile and pharmacokinetics of BCP are discussed, emphasizing its potential as a promising therapeutic agent in colon cancer management. Further clinical studies are ongoing to fully establish the clinical efficacy and therapeutic benefits of BCP in colon cancer treatment.

Keywords: *betacaryophyllene, colorectal cancer, anticancer and anti-inflammatory*

MASS AND VOLUME MODELLING OF CASHEW FRUITS USING THE GEOMETRICAL ATTRIBUTES

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ABSTRACT

Physical properties of agricultural materials are very important in the design of their processing machines and handling systems. Models established based on these physical properties can be useful in the development of automated systems and ensure efficient processing. This study was therefore, designed to determine some physical characteristics of cashew fruits such as the linear dimensions (length, width and thickness), the projected areas along the three mutually perpendicular orientations, and predictive mathematical models for estimating its mass and volume of the fruits were developed using the geometrical attributes. Linear dimensions were within the range of 51.10-89.41 mm, while the projected areas were within the range of 10.51-89.21 mm^2. Average mass and volume were within the ranges of 51.10-156.40 g and 45.70-152.9 cm^3, respectively. The coefficient of determination was used to evaluate the fitness of the developed models. The mass and volume models were divided into three categories: single and multiple variable regression models based on axial dimensions, single and multiple variable regression models based on projected areas, and a single variable regression model based on volume (for mass prediction). In the first classification, mass and volume modelling based on thickness with R^2 ($\geq$ 0.746) was recommended while for the second classification, mass and volume models based on the projected area along the cross-sectional direction was the most suitable model with R^2 ($\geq$ 0.741). There was a good relationship between the mass and volume with R^2 of 0.998 in the third classification. The study's findings indicate that mass and volume modelling based on a single projected area is the most effective method because it relies on a single parameter in computation and is less expensive economically. The developed models can be used in an automated machine for sorting and packaging cashew fruits.

Keywords: Cashew; physical properties; mass/volume modelling; geometrical attribute; shape indicator

FEDSOIL: A JOINT TIME AND ENERGY-EFFICIENT FEDERATED LEARNING-BASED SOIL HEALTH MONITORING FRAMEWORK

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ABSTRACT

Traditional Internet of Things (IoT)-based soil health monitoring systems face several critical challenges, including poor Internet connectivity, high response time, lack of data diversity, and privacy issues, etc., because of the entire data transmission, storage, and analysis on cloud servers. To overcome these limitations, this paper proposes an intelligent framework by combining Federated Learning (FL) and dew-edge-cloud computing. In the proposed framework, the soil data collected using IoT devices are stored inside the microcontrollers for temporary storage during network unavailability through cache-based dew computing. The collected data is then transmitted to the user devices working as the edge nodes when network is available. The edge devices pre-process the data and then use it to train respective local models. In the centralized FL, the edge devices communicate with the cloud server for creating the global model. In decentralized FL, the edge devices communicate among themselves to build the global model. We have experimentally implemented both the centralized and decentralized FL frameworks. As FL is used for creating the model through collaborative learning without sharing raw data, the data privacy is protected. For precise time-series analysis, the Long Short-Term Memory (LSTM) is used to serve as the primary classifier, achieving a good effect on identifying the temporal soil parameter patterns, such as soil moisture, temperature, and nutrient content. Experimental results shows that the proposed framework ensures high prediction accuracy of 95%, and reduces the response time and energy consumption ~85%, compared to cloud-based traditional systems. The experimental results also present that the proposed LSTM-based FL framework outperforms other deep learning classifiers, and existing soil health monitoring approaches. The use of FL for privacy-preserving learning, in combination with LSTM for temporal modelling in the multi-layered network provides a scalable and secure solution for real-time, data-driven soil health monitoring. This whole framework is especially suited for connectivity-limited agricultural settings and represents a sustainable precision farming practices.

WILDSENTINEL: AI-POWERED WILDLIFE CROSSING DETECTOR FOR REMOTE FORESTS

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ABSTRACT

Human-wildlife conflict is a critical issue in forested and hilly regions worldwide, posing significant threats to both human safety and wildlife conservation. In the absence of effective surveillance infrastructure, farmers, forest workers, and tourists are highly vulnerable to unexpected encounters with wild animals, leading to injuries, fatalities, and property damage. The lack of scalable, real-time monitoring systems exacerbates this challenge, particularly in remote or low-connectivity areas.

To address this issue, we have developed an IoT-enabled wildlife detection system that leverages sensor fusion and artificial intelligence. Our solution integrates an ESP32 microcontroller, a camera module, infrared and ultrasonic sensors, and the YOLOv5 deep learning algorithm to achieve up to 98% animal detection accuracy. The system autonomously identifies animal intrusions and delivers real-time visual or audio alerts to nearby human activity zones.

Optimized for energy efficiency and autonomous operation, this system is ideal for deployment in rural or forest-adjacent environments with limited infrastructure. It is cost-effective, scalable, and capable of supporting broader smart surveillance applications. By combining IoT, AI, and cloud computing, the proposed solution contributes to reducing human-animal conflict, enhancing public safety, and promoting sustainable human-wildlife coexistence on a global scale.

Keywords: Human-Wildlife Conflict [1], IoT-based Detection System [2], YOLOv5 Algorithm [3], Real-time Animal Monitoring [4], Autonomous Surveillance [5]

SPATIAL, TEMPORAL, ECONOMIC, AND ENVIRONMENTAL ANALYSIS OF WATER PUMPING SYSTEMS IN THREE ARID REGIONS

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ABSTRACT

Agriculture faces economic and environmental challenges, particularly in water management, especially in arid and semi-arid regions. In these areas, where shallow water tables are accessible and sunshine is abundant, photovoltaic solar energy is an ideal solution for pumping water. It reduces dependence on fossil fuels while being more cost-effective and environmentally friendly.

The adoption of photovoltaic pumping systems can thus improve crop productivity and boost the profitability of irrigated agriculture. This study compares three types of pumping systems—solar photovoltaic, diesel, and butane—in three different regions to assess their cost and their economic and environmental impact.

The results are clear: photovoltaic pumping is the most reliable and sustainable solution. It generates just 2.1 tonnes of CO_2 per year, compared with 29.3 tonnes for thermal pumping. What's more, the cost of pumping water is around 0.5 MAD/m³ for solar power, compared with 2 MAD/m³ for thermal systems, as illustrated in one of the regions studied (1 MAD = 0.1 USD).

Keywords: Photovoltaic Water Pumping, Fossil Fuel Pumping Systems, Spatio-Temporal Analysis, Economic Assessment, Carbon Footprint Reduction

NUTRITIONAL INFLUENCE ON MILK COMPOSITION AND OUTPUT IN DAIRY CATTLE FROM THE MITIDJA PLAIN

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ABSTRACT

Algeria faces a persistent shortage of milk and dairy products, largely due to inadequate livestock nutrition, both in terms of quantity and quality. This study aimed to assess the impact of feeding dairy cows with green alfalfa and alfalfa hay on milk yield and its physico-chemical composition. Twelve Pie Noire dairy cows were selected for the experiment, which was conducted over two periods of four weeks each. During the first period, green alfalfa at the budding stage was compared with two control forages: green barley and green sorghum. In the second period, alfalfa hay was compared to a control diet also based on alfalfa hay but from a different phenological stage.The results revealed that incorporating green alfalfa at the budding stage, as well as alfalfa hay, into the cows' diet significantly improved milk yield, protein content, non-fat dry matter, and milk density compared to the control diets. However, no significant differences were observed in other physico-chemical parameters such as fat content, lactose content, acidity, and freezing point. At the flowering stage, the introduction of alfalfa did not lead to significant improvements in milk production or composition.

Keywords: Alfalfa, milk production, cows, Algeria.

FORMULATION OF AN ARTISANAL FRESH CHEESE INCORPORATING PROBIOTIC LACTIC ACID BACTERIA

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ABSTRACT

The present study aimed to develop a probiotic fresh cheese, considered a functional food, using goat's milk and probiotic lactic acid bacteria belonging to the genera *Lactobacillus* and *Lactococcus*. The selected bacterial strains were first subjected to a comprehensive evaluation of their probiotic properties and technological potential. The probiotic characterization revealed that the strains exhibited strong antibacterial activity, notable resistance to acidic pH and bile salts, and good adhesion capacity to polystyrene microplates an indicator of their ability to colonize the gastrointestinal tract.

The acidifying activity of the strains was also assessed and showed that they possess excellent acidification power, an essential parameter in cheese production for ensuring microbial safety and desirable texture. Microbiological analyses of both the raw goat's milk and the six types of fresh cheese produced confirmed their good microbiological quality, indicating that the production process was hygienically controlled and safe.

Physicochemical evaluations demonstrated that both the milk used and the resulting cheeses met established quality standards in terms of composition, pH, moisture content, and acidity. These parameters remained within the acceptable range, ensuring product stability and consumer safety.

Finally, sensory evaluation revealed high scores across all tested attributes, including taste, texture, appearance, and overall acceptability, suggesting that the incorporation of probiotic

strains did not negatively affect the sensory quality of the cheese. On the contrary, the presence of these beneficial bacteria may have enhanced the product's organoleptic profile.

In conclusion, the study successfully demonstrated the feasibility of producing high-quality probiotic fresh cheese from goat's milk, integrating health benefits with desirable technological and sensory characteristics. Such a product could meet the growing consumer demand for functional dairy foods that promote gut health while maintaining traditional artisanal qualities.

Keywords: functional food, probiotic lactic acid bacteria, goat's milk, fresh cheese.

CRAFTING NUTRIENT RICH BISCUITS WITH BUCKWHEAT AMARANTH AND WHEAT FLOUR

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ABSTRACT

In recent years, the food industry has experienced a significant shift toward the development of nutrient-enriched, functional foods, driven by growing public awareness of health and the need for sustainable dietary practices. Biscuits, a widely consumed snack across all demographics, are commonly made using refined wheat flour, which lacks several key nutrients such as essential amino acids, dietary fiber, and antioxidants. This study investigates the potential to enhance the nutritional composition of biscuits by blending wheat flour with flours derived from pseudocereals such as **amaranth (Amaranthus spp.)** and **buckwheat (Fagopyrum esculentum)**. These grains are noted for their excellent protein quality, complete amino acid profiles, and the presence of health-promoting bioactive compounds with benefits like blood sugar regulation, cardiovascular protection, anti-cancer properties, and blood pressure control.

The experimental framework includes **proximate analysis**, **evaluation of functional properties**, and **assessment of antioxidant activity** of each flour type. These were followed by the development of biscuit formulations with different concentration enriched with the pseudocereal flours. Sensory evaluations were conducted to ensure consumer acceptability in terms of taste, texture, and appearance. The findings indicate that incorporating amaranth and buckwheat significantly improves the biscuits' nutritional value by boosting fiber content, antioxidant levels, and essential micronutrients—without negatively impacting sensory quality. This research supports the use of locally accessible and cost-effective pseudocereals to produce nutritious, functional biscuits that cater to health-conscious consumers, including those adhering to gluten-free or plant-based diets.

OPTIMIZATION OF HYDROLYSIS PARAMETERS FOR MAXIMUM TOTAL SUGAR EXTRACTION FROM VEGETABLE PEEL WASTE USING THERMO-CHEMICAL HYDROLYSIS

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ABSTRACT

This study aimed to optimize the hydrolysis conditions for maximizing total sugar extraction from vegetable peel waste, a byproduct obtained after oil extraction. The pre-treatment process included washing, drying, grinding, and sieving to ensure particle uniformity. Thermo-chemical hydrolysis was employed using hydrochloric acid (HCl) as the catalyst. Eight experimental runs were conducted by varying key parameters: HCl concentration (0.5–3 M), solid/liquid ratio (2–20), temperature (40–80°C), and hydrolysis duration (45–180 min).

The optimal conditions for achieving the highest total sugar yield (206 g/L) were identified as : HCl concentration = 0.5 M, solid/liquid ratio = 10, temperature = 60°C, and duration = 120 min. These parameters ensured efficient breakdown of cellulose and hemicellulose into fermentable sugars while minimizing acid consumption and energy usage. The results demonstrate the potential of vegetable peel waste as a low-cost, renewable feedstock for biofuel and biochemical production, contributing to sustainable waste valorization.

Keywords: *Sugar extraction optimization, Vegetable peel waste valorization, Thermo-chemical hydrolysis, Acid concentration effect, Renewable bioresource*

STUDY OF *IN VITRO* PROPAGATION AND SELECTION FOR SALT TOLERANCE OF LOCAL *Opuntia* CACTUS

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ABSTRACT

Opuntia cactus is a horticultural crop, which is extensively used as food for humans and feed for animals in many countries of the world. This crop has widely adapted to different parts of Tunisia and is an integral part of the culture and economy of arid and semi-arid zones of the country. Recently, to fulfil the demand for large-scale cultivation in a short period by rapid mass multiplication, *in vitro* organogenesis and embryogenesis experiments were conducted with the aim of developing a protocol for *in vitro* propagation of local cactus from areole explants and *in vitro* selection of local cactus for salinity tolerance and resistance. For the first experiment, a reliable strategy was followed for micropropagation of *Opuntia ficus-indica* (L.) and *Opuntia robusta* L. cactus in the presence of the growth regulators, 6-benzylaminopurine (BAP) and metatopolin (mT), at four different concentrations (0.5, 1, 2 and 3 mg/l) and via callogenesis with 2,4-D and picloram at 2, 4, 6 and 8 mg/l. Results of the first experiment revealed that best values of shoot evolution for the 2 cactus species was recorded on media supplemented with 1 and 3 mg/l BAP, mainly. Media with mT lead to vitroplants with less quality. *Opuntia robusta* vitroplantlets show better evolution results than *Opuntia ficus-indica* vitroplantlets. In the second experiment, large and compact calli were initiated on MS medium enriched with 2 and 4 mg/l picloram. For salinity stress tolerance, a decreasing pattern in number and quality of cactus shoots and calli were observed with increasing salinity levels and widely affected at 8 and 10 g/l NaCl. On media with 2, 4 and 6 g/l of NaCl, plantlets show a normal morphologic evolution indicating that cactus can tolerate relatively high salinity levels.

Keywords: Opuntia cactus, mT, *in vitro* propagation, NaCl, salinity stress.

GOVERNANCE, DIGITALIZATION AND MEDICAL RECORD PRIVACY: A LEGAL AND ETHICAL INQUIRY

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ABSTRACT

The rapid digitalization of healthcare systems has transformed the management and accessibility of medical records, offering significant benefits in terms of efficiency, data sharing and patient care. However, this transformation also presents complex legal and ethical challenges concerning the confidentiality and protection of sensitive health information.

This paper explores the intersection of governance structures, technological advancements and privacy rights within the context of electronic health records (EHRs) and broader e-governance frameworks. Through a critical examination of national and international legal instruments, including data protection laws such as the General Data Protection Regulation (GDPR) and health-specific regulations like HIPAA, this study evaluates the adequacy of existing legal safeguards in ensuring patient privacy. In addition, it investigates ethical considerations surrounding informed consent, data ownership and the balance between individual rights and public interest in healthcare innovation.

The paper also highlights governance mechanisms and institutional responsibilities that are essential for upholding privacy standards in digital health infrastructures. Case studies from various countries are used to illustrate the practical implications of differing legal approaches and governance models.

Ultimately, this inquiry argues that effective protection of medical record confidentiality in the digital age requires a multi-layered strategy combining robust legal frameworks, ethical guidelines and accountable governance. Such an approach is vital for building public trust and promoting responsible digital transformation in healthcare.

Keywords: Medical privacy, Digital health, E-governance, Data protection, Legal ethics.

DEVELOPMENT, STANDARDIZATION, AND CONSUMER ACCEPTANCE OF NUTRIENT-ENRICHED HEALTHIER BROWNIE MADE WITH ALTERNATIVE FLOURS AND NATURAL INGREDIENTS

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ABSTRACT

With increasing consumer awareness regarding health and nutrition, there is a growing demand for innovative bakery products made with functional ingredients. This study aimed to develop, standardize, and evaluate a nutrient-enriched healthier brownie using alternative flours and natural ingredients, while also assessing consumer acceptance through a structured survey. Two types of brownies—cakey and fudgy—were formulated using finger millet, dates, and apple pomace, replacing refined flour and sugar to improve nutritional quality. The formulations were optimized based on texture, moisture, and palatability through iterative trials. Nutritional profiling was performed to analyse parameters such as moisture, ash, fat, protein, crude fibre, and antioxidant activity. Textural properties were measured instrumentally. A consumer acceptance study was conducted in two phases: (1) a sensory evaluation using a 9-point hedonic scale involving semi-trained panelists to assess appearance, flavour, texture, aroma, and overall acceptability, and (2) a consumer perception survey to evaluate awareness, preferences, and willingness to purchase healthier bakery alternatives. The results revealed that the millet-based cakey brownie and the date-apple fudgy brownie exhibited significantly enhanced fibre and antioxidant levels compared to conventional brownies. Sensory scores indicated high acceptability across most parameters. The consumer survey showed that over 80% of respondents were willing to shift to healthier bakery options if taste and texture were satisfactory, highlighting strong market potential. This study demonstrates the successful integration of underutilized natural ingredients and by-products in bakery innovation, aligning with both health-focused trends and sustainable food development.

Keywords: Brownie, Health benefits, Consumer behaviour, Food industry, Millets, functional ingredients dates, apple pomace, sensory evaluation, health-oriented bakery, clean label, food innovation.

URBAN AGRICULTURE AND FOOD SECURITY IN CITIES

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ABSTRACT

Rapid urbanization and the increasing vulnerability of global food systems highlight the need for innovative solutions to ensure food security in cities. Urban agriculture, defined as the cultivation, processing, and distribution of food within urban areas, offers a sustainable approach to address these challenges. This paper explores the potential of urban agriculture to enhance food security while contributing to economic, social, and environmental sustainability. The study examines how urban agriculture can mitigate food deserts, reduce food miles, and improve access to fresh, nutritious produce for urban populations. Key technological innovations, such as vertical farming, hydroponics, and aquaponics, are analyzed for their scalability and applicability in dense urban settings. Furthermore, the paper investigates the role of policy frameworks, community engagement, and private-public partnerships in overcoming barriers such as land scarcity, resource management, and economic constraints. Case studies that illustrate successful integration of urban agriculture into urban planning, emphasizing the positive impacts on local economies, community well-being, and environmental resilience is elucidated. The paper concludes by proposing a roadmap for scaling urban agriculture initiatives globally, with recommendations for stakeholders to address policy gaps, foster innovation, and promote sustainable urban food systems. Research underscores urban agriculture as a vital strategy for achieving food security in cities while advancing the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 11 (Sustainable Cities and Communities).

Keywords: Urban agriculture, food security, sustainable cities, vertical farming, urban planning, food systems.

GROWTH PERFORMANCE AND HAEMATOLOGY EFFECTS OF DIETARY MIXTURE OF GINGER (*Zingiber officinale* L.) AND GARLIC (*Allium sativum* R.) ON CATFISH (*Clarias gariepinus* Bruchell 1822) JUVENILES

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ABSTRACT

The present study aimed at determining the effects of medicinal herbs on growth, and hematological parameters on juvenile catfish. This study was conducted to investigate the effects of ginger and garlic as dietary supplements on the growth performance and haematological parameters of *Clarias gariepinus* juveniles using standard methods and procedures for a period of 8 weeks at the University of Abuja research farm, Abuja. In this study, a total of 540 catfish juveniles were used, the fish were randomly allocated into six dietary groups with 30 birds per replicates in a completely randomized design. The control group T6 was fed a basal diet only, while the experimental groups received diets in which ginger and garlic was amended with at different proportions. The treatments were T1 100 % ginger and 0 % Garlic, T2 (75%Ginger and 25% Garlic), T3 (50% Ginger and 50% Garlic), T4 (25% Ginger and 75% Garlic), T5 (0% Ginger and 100% Garlic), the experiment was carried out over a period of 8 weeks. The result shows that the inclusion of T5 (100%garlic) have significantly($p>0.05$) higher growth performance followed by T6 (Control), while T1 (100% ginger) has the lowest growth performance among the treated groups. There were significant differences changes in the heamatology of Clarias gariepinus fed different levels of garlic and ginger, but the highest values for red blood cells (2.68±0.29), heamoglobin (7.17±0.13), packed cell volume (33.4±2.15), mean corpuscular haemoglobin concentration (24.94±1.12) and in lymphocytes (3.09±1.17) were observed in T2 (75% Ginger and 25%Garlic). Highest mean corpuscular volume (146.8±1.59) mean corpuscular haemoglobin(31.21±1.07), and esinophil (0.20±0.01)were seen in T3(50%Ginger and 50%Garlic), while control (T6) has the highest white blood cell (5.85±1.05)and lymphocytes (3.16±1.00)were observed in T6 (Control).This results shows that fish fed withT5 (100% garlic) had better growth and haematology parameters and its therefore recommended for use in fish diet.

GROWTH, YIELD AND QUALITY RESPONSE OF SWEET CORN (*Zea mays* L. *Saccharata Sturt*) ON THE APPLICATION OF *BIOFERTILIZER* DAN TRICHO-COMPOST

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ABSTRACT

Sweet corn production can be improved by organic cultivation by utilizing biofertilizer and compost rich in Trichoderma. This research used Randomized Block Design (RBD) with 6 treatment, single fertilizer recommendation (Urea 300 kg ha^{-1}, TSP 150 kg ha^{-1} and KCL 100 kg / ha (P0), bio fertilizer + tricho-compost dose 20 ton ha^{-1} + half fertilizer (P1), biological fertilizer and trichocompos dose 15 ton ha^{-1} + half of inorganic fertilizer (P2), biological fertilizer and tricho-compost dose 10 ton / ha (P3) + half of inorganic fertilizer, bio fertilizer and tricho-compost dose 5 ton / ha (P4) + half of inorganic fertilizer, biological fertilizer (P5), and each treatment was repeated three times. The results showed that the application of tricho-compost fertilizer with doses of 15 tons ha^{-1} combined with biological fertilizer is a treatment that can reduce the use of fertilizer recommendations by half, resulting in the highest production of sweetcorn and increased respiration and the population of bacteria and fungi in the soil. The technology of biological fertilizer can reduce the recommended dosage of the use of compost so that it can be adopted by farmers.

Keywords: Organic Farming, Plant Nutrition, Trichocompost, Sweet corn

INFLUENCE OF HEAVY METAL CONCENTRATION ON THE DISTRIBUTION BETWEEN MACRONUTRIENTS IN GOAT MILK

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ABSTRACT

The study aims to investigate the distribution of some toxic heavy metals—lead (Pb) , cadmium (Cd) and of an essential trace element, copper (Cu), between the macronutrients of goat milk (casein, whey, and fat) during the acid coagulation process. The goat milk used was sourced from a micro-farm in Suceava County. Three contamination levels were assessed based on the maximum admissible limits established by Regulation (EU) 2023/915 for lead (Pb), Regulation (EC) 396/2005 for copper (Cu), and Codex Alimentarius for cadmium (Cd). Fractional separation of milk components was achieved via a sequential protocol: centrifugation for lipid extraction, followed by acid precipitation controlled via pH monitoring for casein-whey differentiation. Quantification of metal concentrations was performed using flame atomic absorption spectrophotometry (FAAS) for Cu and graphite furnace atomic absorption spectrophotometry (GFAAS) for Pb and Cd.

At contamination levels corresponding to the regulatory maximums (0.020 mg/kg for Pb, 0.010 mg/kg for Cd, and 2 mg/kg for Cu), metal ions showed a predominant affinity for casein (>85%), with limited partitioning into whey (<15%). At medium concentrations of 10 times the maximum permissible limit and high concentrations of 50 times the maximum permissible limit for lead (Pb) and cadmium (Cd) and 25 times for copper (Cu), respectively, a significant copper migration to the lipid phase was observed in a proportion of 30%, while for lead and cadmium an increase in migration to whey was observed in a proportion of 25% for lead and 40% for cadmium, due to saturation of the binding sites in casein. The results highlight the influence of heavy metal concentration on the macronutrients structure in goat milk. Heavy metal (Pb, Cd, Cu) contamination of raw materials significantly influences dairy manufacturing processes, affecting the quality, safety and yield of finished products through their effects on macronutrients.

Keywords: goat milk; heavy metal; metal distribution; food contamination;

THE ROLE OF TECHNOLOGICAL INNOVATION AND THE CIRCULAR ECONOMY IN THE DEVELOPMENT OF SMEs IN THE AGRICULTURAL SECTOR

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ABSTRACT

The paper aims to identify the role of agricultural entrepreneurship for the economy in the digital age, by analyzing the impact of technological innovation and circular economy approaches on the development of agri-food small and medium-sized enterprises (SMEs) as a very important factor in the economic development of a country. The agricultural sector is experiencing a fundamental transformation as a result of two major global trends: the digitalization of the economy and the need for environmental sustainability. Through a theoretical-empirical approach, the study explores the ways in which digital technologies – including precision agriculture, smart sensors, agricultural drones, artificial intelligence and supply chain management platforms – are affecting the improvement of productivity, transparency and sustainability of agricultural SMEs. At the same time, the adoption of circular economy models in agriculture, such as the recycling of organic waste, water reuse, and the circulation of resources in production and processing, is addressed. The study draws on case studies from rural regions of South-East Europe, highlighting good practices, common challenges and the gap between technological potential and actual implementation capacities. Particular attention is also paid to the role of public policies, access to rural finance and the need for digital capacity building among farmers and rural entrepreneurs. The findings highlight that in order to achieve a sustainable transformation of agriculture, it is essential to build a rural innovation ecosystem that connects agricultural entrepreneurship with technology, the circular economy and institutional support. The paper contributes to the academic debate and policy development by providing an integrated framework for increasing the competitiveness, sustainability and resilience of SMEs in the agricultural sector.

Keywords: Agricultural entrepreneurship, Circular economy, Digital transformation, SMEs in agriculture, Technological innovation,

OPTIMIZING GOAT SEMEN CRYOPRESERVATION: IMPACT OF EXTENDER TYPE ON POST-THAW SPERM QUALITY

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ABSTRACT

Semen cryopreservation is an important biotechnology for genetic improvement, biodiversity conservation, and the dissemination of superior traits in goat breeding. Despite significant advancements, the cryopreservation process imposes considerable stress on spermatozoa, leading to structural and functional impairments that compromise post-thaw fertility.

The aim of this study was to evaluate the impact of egg yolk-based and liposome-based extenders on the post-thaw quality of goat sperm, with the objective of identifying optimized cryopreservation protocols that enhance sperm viability, motility, and overall fertility potential.

Recent research has focused on refining cryopreservation protocols specific to caprine semen, emphasizing extender composition, cryoprotectant selection, and antioxidant supplementation. Particular attention is given to the physiological characteristics of goat sperm that influence cryotolerance, including membrane lipid composition and seminal plasma sensitivity. Experimental results demonstrate that extender formulation significantly affects post-thaw motility, membrane integrity, and DNA stability. These findings highlight the necessity of species-specific approaches and the development of standardized evaluation methods to improve reproducibility and fertility outcomes. Enhancing semen cryopreservation techniques in goats will contribute to more effective breeding strategies and sustainable livestock production systems.

Keywords: goat, semen cryopreservation, sperm quality, extender, fertility, biotechnology

DEVELOPMENT OF WHOLE WHEAT BISCUITS FORTIFIED WITH MUSA SPECIES (PARADISICA) INFLORESCENCE

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ABSTRACT

The present study investigates the development and comprehensive characterization of whole wheat biscuits fortified with banana (Musa paradisiaca) inflorescence, a nutritionally rich yet underutilized part of the banana plant. With rising consumer interest in functional and fibre-enriched foods, this research aims to utilize banana inflorescence to enhance the nutritional quality of baked products while promoting sustainable food processing practices. The core objective was to develop a value-added bakery product by incorporating different concentrations of banana inflorescence powder into whole wheat flour and to evaluate the resultant biscuits for sensory, nutritional, physicochemical, and functional attributes. The formulation involved blending whole wheat flour with banana inflorescence powder at varying levels, along with traditional ingredients such as cow ghee, milk, and powdered sugar. The incorporation of banana inflorescence was carefully optimized to maintain product palatability while delivering health benefits. The prepared biscuits underwent sensory evaluation by a semi-trained panel to assess parameters such as appearance, taste, texture, flavour, and overall acceptability. The sensory data revealed that biscuits with moderate levels of banana inflorescence had high consumer acceptability, indicating that the inclusion of this ingredient does not negatively affect sensory attributes and can, in fact, enhance the product's appeal. Proximate analysis was conducted to determine the moisture, fat, ash, protein, fibre, and carbohydrate content of the fortified biscuits. The results showed a significant increase in dietary fibre and ash content with increasing levels of banana inflorescence, reflecting its nutritional contribution. Physicochemical properties such as spread ratio, hardness, and colour values (L\, a\, b*) were also analysed. The addition of banana inflorescence influenced the texture and colour characteristics of the biscuits, with darker hues and slightly firmer textures noted at higher fortification levels. Special emphasis was placed on dietary fibre content due to its known physiological benefits, including promotion of gastrointestinal health. The fibre in banana inflorescence has the potential to undergo fermentation in the colon, leading to the production of short-chain fatty acids (SCFAs) like acetate, propionate, and butyrate, which are known to contribute to gut health, regulate metabolic activity, and exert anti-inflammatory effects. This study demonstrates the viability of using Musa paradisiaca inflorescence as a functional ingredient in baked products.

Keywords: Banana Inflorescence, Fiber-enriched, SCFAs, Antioxidant properties, Functional food, Nutritional enhancement.

DEVELOPMENT THROUGH RESEARCH AND INNOVATION: TÜRKİYE'S STRATEGIC ADVANTAGE FOR CROSS-CONTINENTAL ARTIFICIAL INTELLIGENCE COLLABORATION

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ABSTRACT

To begin with, the development of artificial intelligence in Türkiye shows that the country took crucial steps in the last years in the development, implementation, promotion, and dissemination of artificial intelligence technologies. What is more, reputed specialists worldwide believe that Türkiye's adaptation to artificial intelligence represents a successful model. Furthermore, recent international reports highlight the pivotal position held by Türkiye these days in terms of the strategic advantage for cross-continental artificial intelligence collaboration. The current study addresses the benefits derived from the fact that the country has a strategic location between Europe and Asia which offers a unique advantage in supporting the United Nations' Sustainable Development Goals by leveraging development through research and innovation. In continuation, the research paper centers on the advantages and the challenges faced by Türkiye as a worldwide acknowledged center of artificial intelligence innovation and research, constantly driven by the rapid advancements in the field. The complex analysis tackles the findings displayed in major documents published on Türkiye and artificial intelligence, starting with the country's reports on the National Artificial Intelligence Strategy and continuing with the Türkiye's government steps taken to recognize and promote the importance of artificial intelligence innovation as well as the artificial intelligence adoption across various sectors. In addition, the manuscript delves into outlining the way in which Türkiye focuses on establishing robust governance frameworks with the help of the existing detailed strategy for the artificial intelligence implementation.

Keywords: Türkiye; Sustainable Development Goals; Sustainable Management; Science and Technology; Artificial Intelligence; Artificial Intelligence for Türkiye; Business Administration; Economics; Finance; Management; Accounting; Auditing; Governance Frameworks.

DEVELOPMENT OF INTELLIGENT PACKAGING SYSTEMS FOR REAL-TIME DETECTION OF MEAT SPOILAGE

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ABSTRACT

Consumers are paying more and more attention to food safety. Meat, being a perishable product, is prone to spoilage under the influence of microbiological, chemical and physical factors, and its quality is assessed by sensory, physical, chemical and microbiological analysis. The degradation process involves changes in color, texture, pH, and unpleasant odor resulting from the formation of volatile compounds NH_3 and H_2S.

Industrial methods for monitoring the degree of meat spoilage have been developed, such as pH sensors, gas sensors, biosensors, electronic noses, but these methods are expensive, require digital applications, and the packaging contains electronic components that are not reused.

In order to maintain quality standards, the food industry needs a fast and sustainable method to monitor animal products. In this context the use of intelligent packaging offers an innovative solution for the industry. At the beginning of their development, these systems were based on synthetic colorants (bromothymol blue) but their toxicity has led to a switch to safe and biodegradable plant compounds such as anthocyanins, natural water-soluble pigments of the flavonoid family. These compounds can be extracted from fruits, vegetables, flowers, or food waste (peelings), which account for about 30-50% of the weight of food.

Anthocyanins have a remarkable ability to change their color depending on the pH of the environment, from red in acidic conditions to blue or yellow in alkaline environments. They are also compatible with a wide range of bipolymers (starch, alginate) enabling the development of pH-sensitive films. These characteristics have allowed the realization of a wide range of packaging for different types of meat. The anthocyanin-based film can record the pH variation during the meat alteration process by changing color. So consumers can easily identify spoiled products without opening the packaging. Smart packaging is becoming a necessity to combat food waste and reduce illness.

Keywords: *anthocyanins,intelligent packaging, meat*

A COMPARATIVE ANALYSIS OF EFFICIENCY METRICS IN CVRPTW SETS WITH VARYING NUMBERS OF DELIVERY POINTS

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ABSTRACT

The Traveling Salesman Problem (TSP), one of the oldest and most extensively studied combinatorial optimization problems, has roots tracing back nearly 300 years. Its practical extension into real-world logistics came in 1959 when George Dantzig and John Ramser introduced the Vehicle Routing Problem (VRP), modelling the efficient distribution of goods using a fleet of vehicles. In 1987, Marius Solomon and Antoon Kolen independently laid the groundwork for the Vehicle Routing Problem with Time Windows (VRPTW) and its capacitated version (CVRPTW), proposing heuristics and benchmark datasets that have since become industry standards. Since then, the academic focus has largely remained on minimizing total travel distance or total cost within feasible time windows, especially as exact solution methods (e.g., brute-force algorithms) are only effective for problem sets with fewer than 100 delivery points. For larger-scale problems, heuristic and metaheuristic approaches are widely adopted. However, beyond shortest distance or cost minimization, several other critical performance indicators remain underexplored—particularly route balance, vehicle load distribution, and system responsiveness to dynamic demand shifts. This study seeks to address this gap by presenting a comparative analysis of CVRPTW solution sets that vary in the number of delivery points, all mapped within a fixed geographical plane. The aim is to highlight how increasing the number of delivery points influences not only total travel distance, but also less commonly discussed efficiency metrics that reflect the operational quality and adaptability of the routing system. Such an analysis contributes to a more comprehensive understanding of CVRPTW performance in practical, real-world scenarios.

Keywords: Traveling Salesman Problem (TSP), Capacitated Vehicle Routing Problem with Time Windows (CVRPTW), Demand Management

EFFECT OF BORON CARBIDE REINFORCEMENT ON THE WEAR PERFORMANCE OF Ni–Mo ALLOYED STEEL PRODUCED BY POWDER METALLURGY

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ABSTRACT

Metal–matrix composites (MMCs) combine the ductility and toughness of metallic matrices with the high hardness and wear resistance of ceramic reinforcements, making them ideal for demanding applications in aerospace, automotive, and tooling industries. Powder metallurgy (PM) techniques enable near-net-shape fabrication, uniform reinforcement distribution, and minimal material waste, offering precise control over composite microstructures. Among available ceramic additives, boron carbide (B_4C) stands out due to its exceptional hardness, low density, and chemical stability. The complex interplay of PM parameters and reinforcement levels necessitates systematic evaluation; design of experiments (DOE) methods, especially response-surface methodology (RSM), provide efficient mapping of process–property relationships with fewer experimental trials.

In this study, Ni–Mo alloyed steel powder was reinforced with 1.0 and 1.5 wt.% B_4C via PM processing. The resulting composites were subjected to dry adhesive wear testing using a point-contact pin-on-disc configuration. A DOE based on RSM was employed to evaluate the effects of sliding distance, normal load, and B_4C content on wear performance. Results showed that increasing B_4C reinforcement led to a significant reduction in wear rate, while longer sliding distances and higher loads increased material loss. An empirical model was developed from the RSM analysis to describe the wear behaviour of B_4C-reinforced Ni–Mo steel MMCs.

Keywords: Wear resistance, powder metallurgy, metal matrix composites, boron carbide, response surface method, design of experiment

SMART HELMET WITH EFFECTIVE ALCOHOLIC DETECTION SYSTEM AND EMERGENCY SOS

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ABSTRACT

An accident is a specific, unexpected, unusual, and unintended external action that occurs in a particular time and place with no apparent and deliberate cause but with marked effects. Carelessness of the driver is the major factor in such accidents. The traffic authorities give a lot of instructions to the vehicle operators. But many of them do not obey the rules. Nowadays most countries are forcing motorcyclists to wear the helmets and not to use vehicles when the are in a drunken condition. Every day around the world, a large percentage of people die from road accidents. An effective approach is made to solve the problem by using smart helmets. A smart helmet is a special idea that makes motorcycle driving safer than before. To build a safety system that is integrated with the smart helmet and intelligent bike to reduce the probability of two-wheeler accidents and drunk driver cases. A smart helmet provides help in case of an accident by using GSM and GPS technology. The system consists of two modules: a bike module and a headgear module. The headgear module consists of a capacitive touch sensor, a strap switch, and an alcohol sensor. The bike module consists of an accelerometer, a GPS-GSM module, and an abort switch. The two modules have been designed in such a way to work in sync with each other using wireless communication. A capacitive sensor is placed inside the helmet where the actual human touch can be sensed. This sensor works on the principle of capacitance and has an excellent ability to monitor the change in capacitance. If a biker attempts to start the bike without wearing the helmet, it sends a signal to the bike module, which prevents the ignition. The output capacitance increases if a conductive object touches or approaches the sensor electrode. The strap switch to ensure the fastening of the strap belt of the helmet has been used here. This also ensures that the helmet will not fall off during the ride or sudden impact. Also, the ignition of the bike engine cannot be affected without locking the strap belt; it will not start. Alcohol sensor MQ3 is used here for detecting the alcohol concentration present in the driver's breath. The emergency SOS is inbuilt in the helmet that sends emergency signal to the registered contacts and to the nearest hospital with the exact location of the accident zone. A special feature is also implemented that the helmet have the QR code on the backside which has the details of the rider and also the medical history of the raider that can be accessed only by the hospital. The alcohol sensor is connected to the MCU through an interfacing circuit, and the helmet-sensing switch is directly connected to the MCU. The sensor provides an analog resistive output based on the alcohol concentration. MCU is the microcontroller unit, which controls all the functions of other blocks in this system. The MCU takes or reads data from the sensors and controls all the functions of the whole system by manipulating these data. MCU receives data from these sensors, and it gives digital data corresponding to the output of sensors to the encoder only if the two conditions are satisfied.

Keywords: Drunk and Drive, Enhance road safety, Smart helmet, GPS and GSM, Alcohol Sensor, Ignition Interlock, MCU, Intelligent System, Emergency SOS.

THE INFLUENCE OF GENDER ON UNIVERSITY STUDENTS' ACADEMIC SPENDING IN THE DIGITAL ERA: A CASE STUDY OF STUDENTS IN PADANG

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ABSTRACT

This study investigated the influence of gender on university students' academic spending in the digital era, focusing on students in Padang. Data was collected from 111 students across three universities in Padang: Universitas Negeri Padang, Universitas Metamedia, and Universitas Islam Negeri Imam Bonjol Padang. Student expenditures were categorized into low (< Rp190,000), medium (Rp190,000 – Rp315,000), and high (> Rp315,000) using a percentile approach, as the expenditure data was not normally distributed. A Chi-Square test revealed a statistically significant relationship between gender and academic spending ($\chi^2 = 10.428$; df = 2; p = 0.005). The findings indicate that male students tend to have higher academic expenditures, while female students are more frequently in the low spending category. This difference is likely due to varying learning preferences and styles, digital device ownership and investment, time flexibility and additional activities, social habits and technology access, and how gender influences funding sources. These results highlight the importance of considering gender in developing digital-based educational policies to support students' specific needs.

Keywords: Gender, Academic Spending, Digital Era, University Students, Padang

EFFECTS OF BRAIN FOCUS LEARNING STRATEGIES FOR IMPROVING HIGH PERFORMANCE AMONG SECONDARY SCHOOLS STUDENTS IN RIVERS STATE,NIGERIA

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ABSTRACT

This study examined the effects of Brain focus learning strategies for improving high performance among secondary schools students. The study adopted quasi-experimental research design with pre-test and post-test control group approach. The population for this study consisted of 700 students in public secondary schools in Obio Akpor Local Government Area of Rivers State. A total of one hundred and eighty (180) senior secondary students who are actively engaged in learning mathematics were randomly selected from two selected schools. A purposive sampling technique was used to select two schools (one serves as experimental group while the other serves as control group).Three research questions and three null hypotheses guided the study. The simple random sampling technique was drawn from the sample used for the study. An instrument titled: Brain Focus Learning Strategies Questionnaire (BFLSQ) and Mathematics Achievement Test (MAT) were used in collecting data for the study and it was developed by the researcher. The instrument used for this study was subjected to face and content validation. Test –retest was used to establish the reliability of the instrument and it has index of 0.85. Both primary and secondary sources of data were used to gather information for the study. The information obtained was then analyzed using descriptive and inferential statistics (Mean, Standard deviation. t-test and Anova). The analysis indicated that the use of brain focus techniques in learning strategies proved to be effective method in enhancing students mathematics performance. The study also recommended among others that schools should provide training for teachers on how to implement theses strategies effectively.

Keywords: Brain focus, classroom, learning strategies, high performance

ON SEMICONDUCTOR INDUSTRY AND ITS GROWTH

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ABSTRACT

The semiconductor industry is a cornerstone of modern technological advancement, underpinning innovations in computing, communications, automotive systems, and artificial intelligence. Over the past few decades, the industry has witnessed exponential growth, driven by Moore's Law, advances in fabrication technology, and rising global demand for smart and connected devices. This paper provides a comprehensive overview of the semiconductor industry's historical evolution, key growth drivers, current market dynamics, and future prospects. It examines the shift from traditional silicon-based fabrication to emerging materials and heterogeneous integration, as well as the role of geopolitical factors, supply chain constraints, and government policies. Through data-driven analysis and case studies, the paper highlights the challenges and opportunities facing semiconductor manufacturers, foundries, and design firms in an increasingly AI- and data-centric world. The study concludes with strategic insights into sustaining innovation and resilience in a post-Moore's Law era.

Keywords: Semiconductor Industry, Moore's Law, Chip Design, Semiconductor Market Trends, Integrated Circuits (ICs), Artificial Intelligence Chips, Chip Shortage, CHIPS Act

GREEN BANKING: DRIVERS AND BARRIERS

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ABSTRACT

Sustainable development has influenced all spheres of life, including the banking system. Climate change remains a critical global concern, prompting countries to adopt measures aimed at reducing its negative impact. Banks play a vital role in the economy and make significant contributions to advancing sustainable development goals.

This study aims to analyze the factors that hinder the development of green banking, as well as the advantages associated with its adoption, based on the perceptions of employees in commercial banks in Albania. A total of 200 questionnaires were completed by employees of commercial banks operating in the country. The survey was distributed online and divided into three parts: the first focused on demographic factors, the second on barriers to adoption, and the third on the perceived benefits of green banking.

The results show that key barriers to green banking include the complexity of evaluating green projects, the lack of well-trained staff for green credit assessment, the absence of specific guidelines from the Bank of Albania, the lack of a supportive legal framework from the government, and low demand for green loans. On the other hand, employees identified several advantages of green banking, including higher long-term profits for banks, meeting customer demand, providing environmental benefits, reducing paper usage, and conserving energy.

Keywords: *Green Banking, Sustainable development, Barriers, Advantage.*

REPRESENTATION SYSTEMS AND THE MITIGATION OF PROBABILISTIC FALLACIES

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ABSTRACT

Conditional probability is a fundamental concept in probability theory, essential for decision-making under uncertainty and widely applied in fields such as medicine, engineering, finance, and data science. It provides a framework for updating probabilities as new information becomes available, allowing for more informed predictions and analyses. Despite its importance, conditional probability is frequently misunderstood. Its apparent simplicity often leads to misinterpretations and errors, commonly referred to as probabilistic fallacies. These fallacies, such as the fallacy of the transposed conditional, can result in significant mistakes in reasoning and decision-making. To address these misunderstandings, various representation systems may be used to facilitate the correct comprehension and application of conditional probability. Each system offers unique strengths and limitations in visualizing and solving conditional probability problems. The choice of representation often depends on the specific problem and the user's familiarity with each method. By understanding and appropriately utilizing these tools, students and practitioners can enhance their ability to solve conditional probability problems accurately, thereby reducing the occurrence of probabilistic fallacies.

In this work, we examine three such systems: Venn diagrams, tree diagrams, and contingency tables, and analyze the advantages and disadvantages of each representation system, with a particular focus on their potential to eliminate, or at least mitigate, the probabilistic fallacies that frequently arise when solving conditional probability problems.

Keywords: conditional transposed fallacy, contingency table, probabilistic falacies, tree diagram, venn diagram

THE ROLE OF TOURISM MARKETING IN OPTIMIZING CITY TOURISM IN JORDAN-SOUTH LEVANT - AMMAN CASE STUDY

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ABSTRACT

Digital marketing is a highly effective tool in developing urban tourism by creating a strong digital identity through official websites showcasing attractions, activities, and events, as well as using engaging visual content and user-generated stories to promote the city's appeal. Enhancing visibility on search engines by targeting specific keywords helps boost the city's ranking in search results. Social media platforms play a central role in displaying tourism experiences and collaborating with travel influencers to reach broader audiences. Additionally, paid digital ads and email marketing help directly promote offers and events, while virtual and augmented reality technologies offer interactive previews of destinations, increasing travel intent. Also data analysis is essential for understanding audience behavior and continuously improving marketing performance.

The Greater Amman Municipality has launched several tourism initiatives aimed at enhancing the city's status as a local, regional, and international tourist destination. One of the most notable of these is the "Tourist Trails" project, which was introduced on the occasion of City Day. This project includes the development of 13 diverse tourist routes that cover various areas of Amman. These routes feature historical, archaeological, cultural, and religious sites, such as the Quraysh Trade Route (Ilaf Route), the Baptism Trail (Christian pilgrimage route), the Jordan-Hejaz Railway, the Great Arab Revolt Path, Amman Promenade, the Ammonite Towers, the Amman River Trail, the cultural and heritage tourism route in Jabal Al-Luweibdeh and Jabal Amman.

These routes have been documented and integrated into the "Amman Explorer" platform, an interactive online tool that allows users to explore the trails and tourist sites via digital maps. The municipality is also working to improve the infrastructure of these routes—including road enhancements and tourist facilities—in cooperation with the Ministry of Tourism and Antiquities, the Jordan Tourism Board, several universities, and other specialized entities.

Additionally, the municipality has organized workshops to train tour guides and equip its staff with essential tourism skills, aiming to improve the quality of services provided to tourists and familiarize them with the city's archaeological and historical sites.

Keywords: Tourism, Development, Digital marketing, Jordan, Heritage .

A STUDY OF VARIOUS NEGLECTED AGENTS OF THE GREENHOUSE EFFECT:MOSS AS A CO2 ABSORBENT

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ABSTRACT

The paper aims to explore lesser-known contributors to mitigating the greenhouse effect by examining how certain everyday elements function as carbon dioxide (CO_2) absorbents. Moss, a simple and resilient plant, plays a significant role in capturing CO_2 through photosynthesis, particularly in urban and shaded environments where traditional vegetation may not thrive. Non-ironing clothes, often made from wrinkle-resistant synthetic fibers, indirectly help reduce CO_2 emissions by lowering the need for energy-intensive ironing, thus conserving electricity often produced by fossil fuels. Similarly, white-painted roofs reflect sunlight instead of absorbing it, which reduces the need for air conditioning and, consequently, the associated CO_2 emissions from power generation. Algae, like moss, absorb CO_2 through photosynthesis and can thrive in both aquatic and urban environments. Green walls and rooftop gardens act as living carbon sinks while also insulating buildings and reducing energy use. Biochar, a stable form of carbon-rich material added to soil, helps sequester CO_2 for long periods. Eco-friendly paving materials and natural fiber insulation, such as hemp or sheep wool, also reduce energy consumption and support carbon storage. Simple lifestyle choices like using reusable containers, composting organic waste, and adopting minimalist or circular economy practices can lower emissions from production and waste. Urban tree planting and the creation of microforests help absorb CO_2 and cool cities, while innovative materials like low-carbon concrete continue to absorb carbon long after construction. Collectively, these small but impactful measures, often overlooked in mainstream discussions, can play a vital role in climate mitigation efforts. The main focus of the paper is on moss as an overlooked agent.

Keywords: Algae, Biochar, Composting, Green walls, Low-carbon concrete , Moss.

METABOLIC PROFILING OF GUT-BRAIN AXIS: A STRATEGY TO DECIPHER METABOLITES AFFECTING ALZHEIMER'S DISEASES (AD) DISEASES BY USING METABOLOMICS

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ABSTRACT

The human gastrointestinal tract harbors numerous microbial communities whose true potential has not yet been explored. Through evidences the bidirectional communication between the central nervous system and the gut micro-biome also know as "microbiota-gut-brain-axis" has been revealed. This gut-brain axis regulates brain health, influencing the pathophysiology of Alzheimer's disease (AD).

The correlation between gut microbiota and Alzheimer's disease has evolved as a novel research area with short chain fatty acids (SCFAs) butyrate, propionate, and acetate being identified as a key microbial metabolites influencing pathophysiology of Alzheimer's disease (AD). These metabolites are produced by bacterial fermentation of dietary fibers, playing neuroprotective role by the regulation of neuroinflammation, oxidative stress, and synaptic plasticity. These SCFAs have the ability to cross the blood-brain barrier and exerts anti-inflammatory effects by the reduction of pro-inflammatory cytokines, modulation of microglial activation, and enhancment of histone acetylation, which improves neuronal survival and decline in cognitive functions.

The study aims to investigate the therapeutic potential of SCFAs on AD by the use of integrated metabolomics. Advanced techniques like gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS) will be used to study the perturbations associated with AD. The identified metabolites will be analyzed on the basis of their mass to charge (m\z) ratio using these techniques. Correlation of SCFA levels with cognitive markers, oxidative stress parameters, and amyloid-β aggregation will also be done. It is expected that pateints diagnosed with AD will have reduced levels of SCFAs leading to AD pathophysiology. SCFAs will lead to significant reduction in amyloid burden, oxidative stress, and cognitive decline, along with the restoration of gut microbial balance. This approach will provide a novel and non-invasive strategy for AD management. Additionally this study will support the development of microbiome-targeted therapeutics and personalized interventions based on metabolic signatures.

Keywords: Gut-Brain Axis, Neurodegenrative Diseases, Metabolomics, Short Chain Fatty Acids, Alzheimer Diseases

PHYTOCHEMICAL CHARACTERIZATION AND ANTIOXIDANT, ANTIMICROBIAL, AND ANTIDIABETIC ACTIVITIES OF MOROCCAN *Myrtus communis* L. ESSENTIAL OIL: *In Vitro* and *In Silico* INVESTIGATIONS

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ABSTRACT

Background and Problem Statement: Diabetes mellitus is a chronic disease that is rapidly increasing in prevalence in Morocco, creating a significant health and economic burden. Due to the limitations of conventional treatments, medicinal plants are widely adopted by the population as alternative therapies. In this context, we selected Myrtus communis L. (myrtle), a plant commonly used in Moroccan traditional medicine. Its essential oil (EO) holds promising therapeutic potential but remains underexplored. Considering the growing problem of antibiotic resistance and the prevalence of diabetes, investigating natural alternatives such as EO is both timely and innovative.

Research Objectives: This study aimed to characterize the chemical composition of M. communis EO and evaluate its antioxidant, antimicrobial, and antidiabetic activities using in vitro and in silico approaches.

Methodology: EO was extracted via hydrodistillation and analyzed using GC-MS. Antioxidant activity was assessed using DPPH and FRAP assays. Antimicrobial efficacy was tested against various pathogens. Antidiabetic potential was evaluated through enzyme inhibition assays. Molecular docking predicted bioactivity at the receptor level.

Key Results: Eucalyptol (54.84%) and p-Cymene (19.42%) were major compounds. EO showed strong antioxidant and antimicrobial activity (MIC values as low as 0.019%). It also inhibited α-amylase and α-glucosidase enzymes with IC50 values of 0.179 mg/mL and 0.086 mg/mL respectively, supported by favorable docking scores.

Discussion and Outlook: M. communis EO presents a potent source of bioactive molecules for pharmaceutical use. Further in vivo studies and clinical trials are needed to confirm its safety and efficacy.

Keywords: Diabetes mellitus, Myrtus Communis, essential oil, antioxidant, antimicrobial, antidiabetic.

THE EFFECT OF GAMIFIED MOBILE LEARNING APPS ON ENHANCING CRITICAL THINKING SKILLS IN PRIMARY SCHOOL STUDENTS FOR ENVIRONMENTAL EDUCATION

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ABSTRACT

Gamified mobile learning applications are revolutionizing primary education by engaging young learners in the development of critical thinking, particularly in the context of environmental education. With the Single National Curriculum (SNC) in Pakistan emphasizing both critical thinking and environmental awareness, there is an increasing need for innovative educational tools to address these areas from early education stages. This study explores the impact of gamified mobile learning apps focused on environmental science topics in enhancing the critical thinking abilities of elementary school students in Pakistan. Adopting a quasi-experimental design, 120 students were randomly placed into either an experimental group (using gamified environmental education apps) or a control group (receiving traditional teaching). Standardized instruments assessed students' critical thinking on topics like climate change, sustainability, and ecological problem-solving before and after an eight-week intervention. The quantitative results indicated that the experimental group showed a 24% improvement in critical thinking scores (from 58.3 to 72.4), while the control group experienced an 8% improvement (from 59.1 to 63.9). Qualitative interviews with teachers and students revealed that those using the gamified apps demonstrated enhanced problem-solving skills and a more profound understanding of environmental challenges. The findings suggest that integrating gamified mobile learning platforms focused on environmental education into Pakistan's primary curriculum could significantly improve critical thinking and climate literacy. The paper advocates for policy changes and teacher training to encourage the use of gamified mobile learning in promoting environmental awareness and developing 21st-century cognitive skills in early education.

Keywords: Critical thinking, Environmental education, Gamified learning, Mobile apps.

UNDERSTANDING REGIONAL INEQUALITY IN BULGARIA: A DEMOGRAPHIC AND LABOR MARKET PERSPECTIVE

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ABSTRACT

The territorial distribution of the population, with its demographic and ethno-religious features, combined with the historical and contemporary economic development of Bulgaria, shapes the regional disparities in incomes and unemployment rates as well as the share of the working poor. The country's socioeconomic progress causes the labour market to become more polarized and changes the structural components of employment.

The paper's objective is to elaborate an integrated typology of districts in the country (NUTS 3 level (small regions) according to the EU statistics) according to the specific indicators for demographic situation and the state of labour markets, applying cluster analysis for the selected years 2019 and 2023 (before and after the COVID-19 pandemic). The study results show serious regional disparities: dynamic changes in the scope of districts of each taxon, mainly due to negative trends in demographic development and relatively positive tendencies in the labour market. Furthermore, Sofia (the capital district) has a very distinguished place in the typology due to population size and economic wealth. In addition, the observed regional differences in Northern and Southern Bulgaria's districts are subject to the impact of various factors.

In conclusion, the detailed analysis of these processes will contribute to the improvement and tailoring of regional development policies to reduce the deepening regional economic and social inequalities and address the needs of all stakeholders.

Keywords: population, workforce, unemployment, labour market, Bulgaria

ODOUR CONTROL MEASURES AMONG POULTRY FARMERS IN ENUGU EAST SENATORIAL ZONE, ENUGU STATE, NIGERIA

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ABSTRACT

The study assessed odour control measures among poultry farmers in Enugu east senatorial zone, Enugu State, Nigeria. Multistage sampling procedure was used in the selection of sixty poultry farmers. Data was collected using structured interview schedule. Data was analyzed using frequency, percentage, mean and standard deviation. Results revealed that the poultry farmers odour control measure include: regular cleaning of poultry house ($\bar{x}$=2.91), removing carcasses immediately there is mortality ($\bar{x}$=2.73), locating manure storage away from sensitive receptors ($\bar{x}$ =2.67), cleaning up spillages in the poultry farm ($\bar{x}$= 2.63), and proper ventilation of poultry houses ($\bar{x}$=2.58). Also, result show that the environmental impacts of odour from poultry farm include: poultry odour causes nuisance to the neighbour ($\bar{x}$= 2.25), air pollution through emission of dusts, microorganisms and organic compounds ($\bar{x}$= 2.03), and water pollution ($\bar{x}$=2.02). Data show that the perceived effects of odour from poultry farms on the health of farmers include: loss of appetite, stomach discomfort ($\bar{x}$=2.20), and difficulty in breathing ($\bar{x}$=2.03). Result show that the farmers waste management practices were: drying of the poultry manure and bagging for sale (95.0%), use of manure for improving plant growth (86.7%), and land filling techniques (53.3%). The poultry farmers should be trained by government through the organization of workshops where these poultry farmers will be educated on emerging technologies such as addition of bentonite to poultry feed during feed formulation to control odour.

Keywords: Poultry, Farming, Odour control

THE FUNCTION AND RESPONSIBILITIES OF JUDICIAL POLICE OFFICERS IN THE COURSE OF PRELIMINARY CRIMINAL INVESTIGATIONS

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ABSTRACT

This paper focuses on the responsibilities and functions of Judicial Police Officers during the preliminary investigation phase of a criminal case. As subjects of the criminal judicial process, they actively participate and engage alongside the prosecuting authority from the initiation of proceedings through to their execution.The paper also aims to analyze the legal framework that governs the activity of Judicial Police Officers in the Republic of Albania, focusing on their organization, legal status, roles, and functions, as well as the provisions regulating their relationship with the Prosecutor's Office and other justice institutions. The justice reform brought significant changes to domestic legal acts, including the Criminal Procedure Code and the enactment of the Law on the Organization and Functioning of the Judicial Police, which introduced substantial organizational improvements to strengthen the investigative role of Judicial Police Officers and reaffirmed the leading role of prosecutors. We have analyzed the importance of the amendments to procedural criminal legislation and the improvements brought by the justice reform. Moreover, we have examined the legal provisions related to the preliminary investigation phase, the active role of Judicial Police Officers, and their initiative-driven actions, particularly in cases of flagrant offenses. We have also highlighted the collaborative role and legal obligations of officers in relation to the Prosecutor's Office, outlining all the competencies and actions they must undertake to ensure a due legal process. Finally, the study presents several conclusions and recommendations aimed at further improving law enforcement and aligning it with European Union directives. The research methodology employed in this paper integrates historical, analytical, descriptive, comparative, and statistical methods, which are interrelated in a manner that ensures a comprehensive and effective examination of the subject under study.

Keywords: Officer, preliminary investigations, reform, Prosecutor.

STRUCTURAL AND ELECTRICAL CHARACTERIZATION OF SRF_2-MODIFIED PZT CERAMICS NEAR THE MORPHOTROPIC PHASE BOUNDARY

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ABSTRACT

This work focuses on the synthesis and electrical characterization of SrF_2-modified lead zirconate titanate ceramics, with the general formula $Pb_{1-x}Sr_x(Zr_{0.43}Ti_{0.52})(Al_{0.5}Sb_{0.5})_{0.05}O_{3-x}F_{2x}$, referred to as PZT-SASF. The ceramics were synthesized via the conventional solid-state route, targeting compositions near the morphotropic phase boundary (MPB) to optimize ferroelectric performance. X-ray diffraction (XRD) analysis confirmed the coexistence of tetragonal and rhombohedral phases, indicative of MPB behavior. Scanning electron microscopy (SEM) revealed a microstructure composed of large, irregular grains with noticeable microporosity.

Electrical properties were investigated using impedance spectroscopy and electric modulus analysis over a frequency range of 0.1 kHz to 1 MHz and a temperature range of 300–700 K. The results demonstrate a strong dependence of dielectric behavior on the grain structure. Nyquist plots showed distinct semicircular arcs attributed to grain contributions, allowing for detailed analysis using an equivalent circuit model. Fitting procedures across all temperatures enabled the extraction of grain resistance and capacitance values. Notably, the co-substitution of Sr^{2+} at Pb^{2+} sites and F^- at O^{2-} sites resulted in an enhancement of the dielectric constant, particularly at elevated temperatures, highlighting the potential of this doping strategy for improved electrical performance.

Keywords: PZT-SASF ceramics; SrF_2 doping; Solid-state synthesis; Impedance analysis; Dielectric enhancement; Grain contribution; MPB.

OPERATIONALIZED MEASUREMENT PROCESS FOR MODEL-QUALITY-EVALUATION IN CASE OF DATA ASSETS BASED ON QUESTIONNAIRES

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ABSTRACT

History: The quality of data assets can be massively different: from the randomized data to mechanistic relationships between observed phenomena. In general, questionnaires deliver fewer valuable data than classic measurements. Therefore, it is relevant to be capable of estimating data quality of data assets coming from questionnaires. The previous experiments defined operationalized processes for model-quality-evaluations in order to derive suspicious persons (objects) and/or questions based on the difference between estimation and fact concerning each questionnaire-position.

Background and benchmarks: Here and now, a questionnaire (2011-2022) concerning human beings (20.000+), especially their life-parameters (e.g. sleeping-quality, sport-activity, smoking, etc. – 4 groups as X: 2 binary, 1 unit with three options, 1 unit with 4 options and one attribute as Y – with 5 options: see self-evaluation of the own life quality) are focused in order to construct a model series being capable of highlighting differences between the quality of randomized, real, and ideal data assets, where the randomized and the ideal data assets are the benchmarks and the quality of the real (questionnaire-based) data should be measured on the scale defined by the two extreme alternatives (randomized and ideal data assets).

Highlighted details: The randomized data positions follow the internal relationships of the real data (e.g. binary X-case: ratio of smoking in percent = 100% - ratio of no-smoking / case of 5 Y-options: ration of life quality on level 5 + on level 4 + on level 3 + on level 2 + on level 1 = 100%). The OAM (object attribute matrix) for generation of production functions had 11 objects (years – 2014 is missing) and 11 X-attributes + 5 Y-attributes. A model (Y=f(Xi)) is good, if the Y-values (ratios) in each level of 1-2-3-4-5 can be derived from the constant (ranked) Xi-matrix in a parallel way based on a direction vector for the attributes being defined by experts (by the authors of the questionnaires: e.g. the higher ratio on no-smoking-option leads to higher ration of better life quality levels). The models for each Y-level deliver not only differences between facts and estimations, but also importance of the 11 attributes in each model and/or correlation values between Xi and Yj. Predefined rules for model-evaluation: The ideal data assets should have correlation values exactly as 1.00, the randomized data assets should have lower correlation values as real data assets. The volume of estimation errors should be higher in case of randomized data assets than in case of real data assets. The number of antagonistic objects should be higher in case of randomized data assets than in case of real data assets, etc. Result: the questionnaire-based data asset is better than the randomized one and the real data asset produced no suspicious modelling details – based on a totally algorithmizable/operationalizable process!

Future aspects: The observed data asset through the questionnaires can be seen in this first project layer as a group of relatively good interpretable X-phenomena (c.f. ever smoking yes/no, etc.). It means that these data could have been collected based on classic measurements. On the

other hand, there are existing such attributes, where the answers (X-variables) deliver intuitive feelings (like already in case of the Y-variables). It is to expect, that the less measurable X-data will lead to less qualitative modelling results. Therefore, the own “data-quality-meter” should deliver lower index values based on the trivial anti-discriminative principle: Can each data asset have the same quality index?

Keywords: consistency, automation, questionnaire, randomized data, benchmarking

THE HIDDEN POWERS OF TERT-BUTANOL IN CATALYSIS

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ABSTRACT

In aqueous dye-sensitized solar cells (DSSCs), dicyanobis(2,2'-dipyridyl)iron(III) acts as an active sensitizer that oxidizes iodide, allowing it to revert to its reduced form and become excited by absorbing light again. Therefore, this key oxidation-reduction process needs to happen rapidly, a goal that can be achieved through homogenous catalysis. Utilizing homogenous catalysis could improve the efficiency, affordability, and environmental sustainability of a DSSC by using a small amount of a non-toxic, eco-friendly solvent mixed with water. This can lead to a faster reaction rate and enhanced stability, as well as reduced costs due to the presence of water. As a result, this study aims to use tert-butanol as a catalyst to speed up the reaction involving dicyanobis(2,2'-dipyridyl)iron(III) and iodide in an aqueous setting. The reaction's operational parameters were optimized in order to suggest a feasible mechanism for the catalytic impact of tert-butanol.

TRANSFORMING TRASH INTO TREASURE FOR WASTEWATER CLEANUP

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ABSTRACT

In this research, waste materials have been utilized to purify wastewater. Dyes are widely utilized in various industries, and their discharge can adversely affect both aquatic organisms and humans. Malachite Green (MG), one of these synthetic dyes, is commonly employed in the textile, paper, leather, stained glass, and several other sectors due to its strong coloring capability and high stability. It is important to eliminate or reduce its concentration prior to its release into water bodies to prevent or manage the onset of various diseases associated with MG. In this study, the MG dye was removed from water using a 1:1 blend of powdered waste materials, including pomegranate peels, corncobs, almond, peanut, and walnut shells. Under optimal conditions, the dye adsorption reached almost 100%. Hence, a combination of biosorbents can be effectively employed in real-world applications to remove hazardous soluble substances from water sources.

FULL TEXTS

USING ARTIFICIAL AFTERIMAGE ALGORITHM FOR RAINFALL PREDICTION

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ABSTRACT

Rapidly developing technology enables digital devices to become widespread in every field. As a natural result of this; very different devices have started to be used in many fields such as engineering, social and human sciences, entertainment, finance, health, banking, education. This means that an increasing data mass is formed in every field. As data continues to form at increasing speeds, it has become almost impossible to analyze and make sense of them with manual methods or known analytical methods. This situation has led to software becoming a solution-oriented service in many fields. Especially in fields that require multidisciplinary work, there is a great need for study subjects such as artificial intelligence, artificial learning, machine learning and data mining. Because it has become very difficult to analyze the multidimensional and large amounts of data at hand with classical methods.

Optimization is the name of searching for the optimum, or most ideal, solution for a problem. In optimization problems, strategies for solution can be classified as analytical, numerical and intuitive. Meta-Heuristic methods are a solution methodology used for optimization purposes in computer science. It seeks to solve problems by imitating the events and systems that exist in nature. In this study, the Artificial Afterimage Algorithm, a newly introduced heuristic method, was used to make rainfall predictions. For this purpose, the application of rainfall prediction was performed on the Rainfall Prediction using Machine Learning dataset obtained from the Kaggle database. As a result of the experimental studies, the best Accuracy value was 0.85, the best Precision value was 1, the best Recall value was 1 and the best F1 value was 0.869. These results showed that the Artificial Afterimage Algorithm, a newly introduced algorithm in the literature, can be successfully applied.

Keywords: Artificial Afterimage Algorithm, Clustering, Rainfall Prediction

YAĞIŞ TAHMİNİ İÇİN YAPAY AFTERİMAGE ALGORİTMASININ KULLANILMASI

ÖZET

Hızla gelişen teknoloji, her alanda dijital cihazların yaygınlaşmasını sağlamaktadır. Bunun doğal bir sonucu olarak; mühendislik, sosyal ve beşeri bilimler, eğlence, finans, sağlık, bankacılık, eğitim gibi birçok alanda çok farklı cihazlar kullanılmaya başlanmıştır. Bu durum, her alanda gün geçtikçe artan bir veri yığını oluşması demektir. Veriler artan hızlarla oluşmaya devam ettikçe, bunları manuel yöntemlerle ya da bilinen analitik yöntemlerle analiz etmek ve anlamlı hale getirmek neredeyse imkânsız hale gelmiştir. Bu durum birçok alanda yazılımların gün geçtikçe çözüm odaklı bir hizmet olmasını beraberinde getirmiştir. Özellikle multidisipliner çalışma gerektiren alanlarda, yapay zekâ, yapay öğrenme, makine öğrenmesi ve veri madenciliği gibi çalışma konularına çok fazla ihtiyaç duyulmaktadır. Çünkü eldeki çok boyutlu ve aynı zamanda çok miktarda olan verileri klasik yöntemlerle analiz etmek çok güç hale gelmiştir.

Optimizasyon bir probleme ilişkin optimum yani en ideal olan çözümü aramanın adıdır. Optimizasyon problemlerinde, çözüme yönelik stratejiler; analitik, nümerik ve sezgisel olarak sınıflandırılabilir. Meta-Sezigsel yöntemler, bilgisayar bilimlerinde optimizasyon amacıyla kullanılan bir çözüm metodolojisidir. Doğada var olan olayları ve sistemleri taklit etme yoluyla problemlere çözüm getirme arayışındadır. Bu çalışmada literatüre yeni girmiş olan bir sezgisel yöntem olan Yapay Afterimage Algoritması yağış tahmini yapmak için kullanılmıştır. Bu amaçla Kaggle veri tabanından elde edilen Rainfall Prediction using Machine Learning veri seti üzerinde yağış tahmini uygulaması gerçekleştirilmiştir. Deneysel çalışmalar sonunda elde edilen en iyi Accuracy (Doğruluk) değeri 0.85, en iyi Precision (Kesinlik) değeri 1, en iyi Recall (Duyarlılık) değeri 1 ve en iyi F1 değeri ise 0.869 olarak elde edilmiştir. Bu sonuçlar, literatüre yeni kazandırılmış bir algoritma olan Yapay Afterimage Algoritmasının başarı ile uygulanabildiğini göstermiştir.

Anahtar kelimeler: Yapay Afterimage Algoritması, Kümeleme, Yağış Tahmini

Giriş

Bilgi kavramı insanoğlu için her devirde en önemli kavram olmuştur. Sosyal hayat, sağlık, astronomi, yönetim vb. hayatın her alanını ilgilendiren konularda ve hatta savaşlarda bile bilgi her zaman en önemli yönlendirici enstrüman olmuştur. Teknoloji geliştikçe bilgiye ulaşma ve onu analiz etmenin şekli değişmiştir. Aslında bilginin kaynağı veridir. Veri ise, bilginin ham yani işlenmemiş halidir. Ölçme, sayma, deney yapma, gözlem veya araştırma ile elde edilebilir (Özmen, 2016). Veri işlenerek anlamlı bir hale gelir ve sonuçları çok şey ifade edebilir.

Bir çöp yığını gibi görülen çok büyük veri ambarlarında aslında çok anlamlı bilgilerin barındığı son yıllarda yapılan büyük veri ve veri madenciliği çalışmaları ile ortaya çıkmıştır. Veri madenciliği, çok büyük miktardaki verilerin içerisindeki ilişkileri inceleyerek, veriler arasındaki bağlantıları bulmaya çalışan ve veri içinde gizli kalmış bilgilerin çekilmesini sağlayan veri analizi tekniğine verilen isimdir (Kalikov, 2006).

Bilgisayar ve yazılım teknolojisinin henüz çok ilerlemediği yıllarda bu bilgilerin keşfi manuel yapılmaktaydı. Dolayısıyla bu bilgiyi keşfedebilmek oldukça güç ve hatta bazen imkansızdı. Fakat bu alandaki çok hızlı gelişme, bu süreçlerin artık bilgisayarlar yoluyla yapılmasının önünü açtı. Veriyi işlemek adına yapılan tüm süreçler artık bilişim teknolojileri yardımıyla yapılabilmektedir. Artık klasik donanım ve yazılımlarla depolanması ve analiz edilmesi zor olan büyük verileri yeni bilgi teknolojileri, ve yazılımlar aracılığıyla depolamak, işlemek, ve analiz etmek mümkün hale gelmiştir (Köseoğlu & Demirci, 2017).

1. Yapay Zeka ve Yapay Öğrenme

Yapay zeka ilk , 1956 yılında John McCarthy, Marvin L. Minsky, Nathaniel Rochester ve Claude E. Shannon tarafından tanımlanmıştır (McCarthy et al., 1955). Ancak yapay zekanın mucidi John McCarthy olarak kabul edilmektedir (Alpaydın, 2011). McCarthy yapay zekayı, insan benzeri zeki makineler özellikle de zeki bilgisayar programları yapma bilimi ve mühendisliği" olarak ifade etmiştir (McCarthy, 2004). Şöyle ifade edebilir: Bilgisayarların akıllı davranma, anlam çıkarabilme, problem çözme ve genelleme yapabilme gibi insana özgü davranışlarda bulunabilmesi, yani bilişsel becerileri gösterebilmesi yapay zeka olarak nitelendirilmiştir (Arslan, 2020).

Makine öğrenmesi ise yapay zekanın altında bir bilim alanıdır. Diğer bir ismi ise Yapay Öğrenmedir. Bu kavram ilk defa Arthur Lee Samuel tarafından kullanılmıştır. Makine öğrenmesi için: "Bilgisayarların açık bir şekilde programlamadan öğrenme gerçekleştirmesine olanak tanıyan bir araştırma alanıdır" şeklinde bir ifade kullanmıştır (Mockenhaupt, 2021). Başka bir ifadeyle yapay öğrenme, bilgisayarların bir problemi çözmekte örnek veri ya da deneyimi kullanacak biçimde programlanmasıdır (Alpaydın, 2011).

Veri madenciliği de, yapay öğrenmenin altında bir alandır. Büyük ölçeğe sahip verilerin içerisinden bilgiye erişebilme, bilgiyi ortaya çıkarabilme veya büyük veri yığınlarından ilerisi için tahminde bulunabilme için bağıntıların bilgisayar programları kullanılarak keşfedilmesi olarak tanımlanabilir (Pektaş, 2013).

Veri madenciliği aynı zamanda, büyük miktardaki veriler içerisindeki ilişkileri analiz ederek verilerin arasındaki bağlantıları keşfetmeye yardımcı olan ve veri içindeki keşfedilmemiş bilgilerin alınabilmesine yarayan analiz tekniğidir (Kalikov, 2006). Uygulama alanı oldukça geniştir. Yapay öğrenme, veri tabanı sistemleri, görselleştirme, yapay sinir ağları, istatistik, gibi birçok disiplinle ilişkilidir. (Savaş, S. et al., 2012).

2. Sezgisel Yöntemler

Sezgisel yöntemler, yapay öğrenme (makine öğrenmesi) alanının içerisinde yer alan ve özellikle lineer olmayan gerçek dünya problemlerinin çözümünde çok işe yarayan bir metodolojidir. Doğadaki var olan sistemler ve olayları taklit ederek problemlere çözüm getirmeye çalışır.

Genel olarak yaklaşım metodolojisi en iyi olan çözüme benzemeye çalışmaktır. En iyi çözümün etrafında çözümler üreterek elde edilmeye çalışılan optimum çözümü elde etmenin peşindedir. Bu amaçla en iyi çözümün etrafında matematiksel olarak gezmeye çalışır. Bunun için her sezgisel yöntemin kendine ait matematiksel bir alt yapısı vardır.

Sezgisel yöntemler insan beyni (McCulloch & Pitts, 1946), balinalar (Mirjalili and Lewis, 2016), arılar (Karaboğa, 2005), insan bağışıklık sistemi (Alataş & Akın, 2004), gri kurtlar (Mirjalili, S. et al., 2014), kuş ve balık sürüleri (Kennedy et al., 1995), ateş böcekleri (Yang, 2008), yarasalar (Yang, 2010), yer çekimi (Rashedi et al., 2009) vb. birçok canlıyı ve olayı taklit etmeye çalışmaktadır. Her yöntemin matematiksel alt yapısı farklı olmakla beraber temel yaklaşımı aynıdır. Asıl olan en iyi çözüme benzeyerek ideal olan çözüme kavuşmaktır.

2.1. Yapay Afterimage Algoritması

Yapay afterimage algoritması (Demir, 2025), görme olayındaki kavramları taklit ederek problemlere çözüm getirmeye çalışan bir sezgisel algoritmadır. Görme olayındaki pozitif ve negatif afterimage, görsel açı ve algısal boyut kavramlarını temel alarak bir çözüm sunar.

Işık saçan bir cisme belirli bir süre boyunca bakmaya devam ettiğimiz takdirde, gözlerimizi kapatmamız halinde bile bir süre cismin görüntüsünü görmeye devam ederiz. Beynimiz belirli bir süre görüntüyü oluşturmaya devam edecektir. Bu olaya afterimage denilir. Görüntü bazen cismin renkleriyle ayın ama daha belirsiz bir şekilde olacaktır. Bu pozitif afterimage; gözlerimizi kapatmadan fakat cisme bakmadan nötr bir zemine bakmaya devam edecek olursak da cismi tamamlayıcı renkleriyle görmeye devam ederiz ki buna da negatif afterimage deriz.

Cismin gözümüzdeki görüntüsünün oluşmasında cismin boyutu ve göze olan uzaklığının etkisi vardır. Bu değerler altında gözün algıladığı değer olan görsel açı kavramı Denklem (1)'de ifade edilmiştir.

$$V = 2 * \arctan\left(\frac{cismin\ boyutu}{2 * göze\ olan\ uzaklığı}\right) \quad (1)$$

Gözün görsel açı altında algıladığı boyut ise, algısal boyut olarak isimlendirilir. Denklem (2) algısal boyutun formülünü göstermektedir. D cismin göze olan uzaklığını ifade eden değerdir.

$$S = V * D \quad (2)$$

Yapay afterimage algoritması, Denklem (1) ve Denklem (2)'yi kullanarak bir sezgisel alt yapı sunmaktadır. Denklem (3), (4) ve (5) bu algoritmanın temel denklemlerini göstermektedir.

$$V = 2 * \text{atan}\left(\frac{pop_{i,j}}{2 * pop_{i,j} - best_{1,j}}\right) \quad (3)$$

$$S_{i,j} = V * (pop_{i,j} - best_{1,j}) \quad (4)$$

$$New\ pop_{i,j} = S_{i,j} + (|S_{i,j} - (best_{1,j} - |(worst_{i,j} - pop_{i,j})|) * rand) \quad (5)$$

Best, hesaplanan en iyi çözümdür ve pozitif afterimage kavramını temsil eder.

Worst, o adımdaki en kötü çözümdür ve negatif afterimage kavramını temsil eder.

$pop_{i,j}$, aday çözümlerin içerisinde en iyiye aday olan her çözüm değeridir.

3. Veri Kümeleme

Veri madenciliğinde kullanılan yöntemler eğiticili ve eğiticisiz öğrenme yöntemleri olarak temel iki guruba ayrılır. Eğiticili öğrenmede, eldeki verilerin sınıf değerleri bilinmektedir ve algoritmanın eğitimi için kullanılır. Eğiticisiz öğrenmede ise, eldeki kümelerin sayısı ve küme bilgisi kullanılmadan sadece niteliklerin birbirlerine olan yakınlıkları kullanılarak sonuca gidilmeye çalışılır. Kümeleme analizinde, grup içinde maksimum benzerlik ve gruplar arası maksimum farklılık mantığına göre hareket edilir (Dudoit & Fridlyand, 2002).

Kümeleme analizinde kullanılan karışıklık matrisi, bir sınıflandırma modelinin doğru veya yanlış tahmin edilen örneklerin sayısını gösterdiği matristir. Tablo 1 karışıklık matrisini göstermektedir (Tan et al., 2014).

Tablo 1. Karışıklık matrisi

	Gerçek pozitif	Gerçek negatif
Tahmin edilen pozitif	True pozitif (TP)	False pozitif (FP)
Tahmin edilen negatif	False negatif (FN)	True negatif (TN)

Tablodaki pozitif ve negatif kavramları genel bir ifadedir. Uygulamada bunlar kümelenecek olan gurupların isimleri olacaktır. Ayrıca gurup sayısı verideki küme sayısı kadar artacaktır. Örneğin hasta-sağlıklı veya düşük-orta-yüksek şeklinde kümeler olması halinde küme sayısı ve sütun sayısı değişecektir.

Kümelemede performansı ölçmek için ise; accuracy, precisioni, recall ve F1 skor değerleri kullanılır. Accuracy ile modelin ne kadar doğru çalıştığı, precision ile sonuçların ne kadar geçerli olduğu, recall sonuçların ne kadar eksiksiz olduğunu gösterir. F1 skor ise precision ve recall değerlerinin harmonik ortalamasıdır ve ikisi arasındaki dengeyi ifade eder. Denklem (6), (7), (8) ve (9) bu değerlere ilişkin formülleri göstermektedir (Tan et al., 2014).

$$Accuracy = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} \tag{6}$$

$$Precision = \frac{\text{TP}}{\text{TP+FP}} \tag{7}$$

$$Recall = \frac{\text{TP}}{\text{TP+FN}} \tag{8}$$

$$F1\ skor = 2 * \frac{\text{Precision*Recall}}{\text{Precision+Recall}} \tag{9}$$

4. Deneysel Sonuçlar

Bu çalışmada Kaggle veri tabanından elde edilen Rainfall Prediction using Machine Learning veri seti üzerinde çalışılmıştır. Veri seti 12 tane öznitelikten oluşmaktadır. İlk öznitelik gün numarası olduğundan çıkarılmıştır. Kümelemeye etkisi olmayan bir özniteliktir. Bir

öznitelik ise yağış olup olmadığını gösteren özniteliktir. Tahmin edilmeye çalışılan değerdir. Kümelemede çıkış özniteliği kullanılmayacağından eğitim esnasında bu öz nitelik çıkarılarak çalışılmıştır. Toplamda 366 adet örnek vardır. Yağış olan ve olmayan 2 gurubun her birinden 20 örnek ayrılmış ve test için kullanılmıştır. Algoritma çıktı olarak best, worst değerlerini ve görsel açı değerini vermektedir. Her denemede algoritma 5000 kez çalışacak kadar denenmiştir. Elde edilen değerler Tablo (2), (3) ve (4)'te gösterilmektedir.

Tablo 2. Best matris değerleri

best									
177.949	11.504	20.919	10.560	16.897	31.210	19.753	18.610	8.342	34.885

Tablo 3. Worst matris değerleri

worst									
3.215	4.134	7.940	1.680	2.692	2.153	8.104	4.789	2.853	8.611

Tablo 4. Görsel açı değeri

V
15.121

best, worst ve V değeri kullanılarak, denklem (3),(4) ve (5) yardımıyla elde edilen küme aralıkları Tablo (5)'deki gibidir. Bu aralıklar test için ayrılan 2 gurubun test best matris ile farklarını göstermektedir. Kümelemede asıl olan öz niteliklerin farklarına göre gurupları mümkün olduğunca birbirinden ayırmaktır. Algoritma bu mantıkla yağış olacak y ada olmayacak durumların tahminini birbirinden ayırırken hesaplanan bu fark değerlerine göre sonuç vermektedir. Küme 1 yağış olmadığı durumları, Küme 2 ise yağış olduğu durumları temsil etmektedir. Tabloda koyu renkle işaretlenen kısım, normalde Küme 2'nin aralığındadır. Bu durumda bu kısım hata olarak değerlendirilmiştir.

Tablo 5. Küme aralıklarının fark değerleri

Küme1	Küme2
934.7	1017.2
950.2	1021.3
998.3	1023.7
998.5	1025.1
1012.4	1030.1
1013.3	1045
1014.8	1045.4
1028.9	1054.6
1052.4	1055.1
1055.3	1057.7
1064.6	1058.5
1065.1	1061
1075.7	1063.4
1111.5	1063.9
1187.7	1064.3
1210.3	1065.3
1211.6	1066.4
1213.9	1067.1
1220.8	1069.2
1226	1091.6

Şekil (1) ise, test değerlerinin karışıklık matrisini göstermektedir.

Gerçek değerler

Tahmin edilen değerler		Yağış yok (0)	Yağış var (1)
	Yağış yok (0)	14	6
	Yağış var (1)	0	20

Şekil 1. Karışıklık matrisi değerleri

Karışıklık matrisindeki değerler, Denklem (6), (7), (8) ve (9) kullanılarak hesaplandığında;

Yağış yok kümesi için:

$$Accuracy = \frac{14+20}{14+20+6+0} = \mathbf{0.85}$$

$$Precision = \frac{14}{14+6} = \mathbf{0.7}$$

$$Recall = \frac{14}{14+0} = \mathbf{1}$$

$$F1\ skor = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} = \mathbf{0.824}$$

Yağış var kümesi için:

$$Accuracy = \frac{20+14}{20+14+0+6} = \mathbf{0.85}$$

$$Precision = \frac{20}{20+0} = \mathbf{1}$$

$$Recall = \frac{20}{20+6} = \mathbf{0.769}$$

$$F1\ skor = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} = \mathbf{0.869}$$

2 küme için en iyi Accuracy= 0.85, Precision =1, Recall=1 ve F1 skor= 0.869 çıkmıştır.

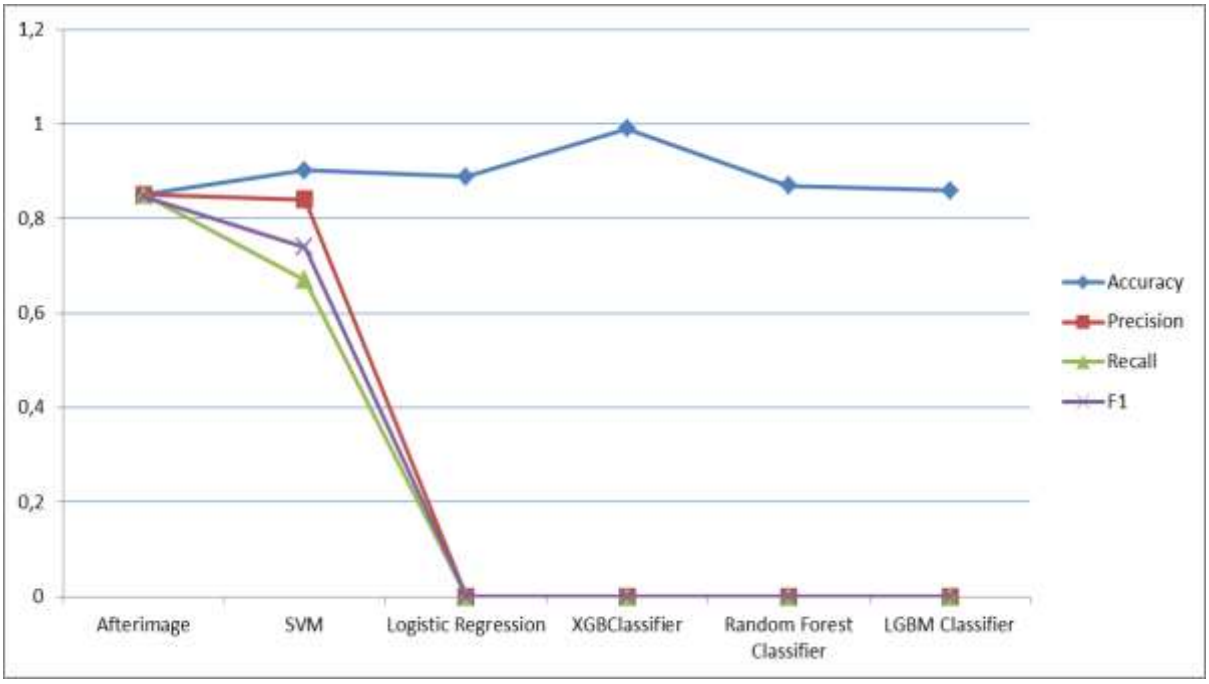
Her iki küme için ortalama değerler ise: Accuracy = 0.85, Precision= 0.85, Recall = 0.85, F1 skor= 0.847 çıkmaktadır. Şekil (2), her iki küme için performans metriklerinin değerlerinin grafiğini temsil etmektedir.

Literatürde bu veri seti ile yapılan çalışmaların sonuçları ve bu çalışma ile karşılaştırması Tablo (6)'da gösterilmiştir. Bu çalışmanın performans metriklerinin ortalama değerleri tabloda verilmiştir.

Tablo 6. Performans metriklerinin literatür karşılaştırması

	Afterimage	**SVM**	**Logistic Regression**	**XGBClassifier**	**Random Forest Classifier**	**LGBM Classifier**
Accuracy	0,85	0,902	0,889	0,99	0,87	0,859
Precision	0,85	0,84	-	-	-	-
Recall	0,85	0,67	-	-	-	-
F1	0,847	0,74	-	-	-	-

Şekil (2), Tablo(6)'da karşılaştırılan durumların grafiksel temsilini göstermektedir.



Şekil 2. Performans metrikleri karşılaştırması grafiksel gösterimi

5. Sonuç ve Tartışma

Özellikle doğrusal olmayan problemlerin çözümünde klasik çözüm yöntemleri çok sorun yaşayabilmektedir. Parametreler arasındaki ilişkinin keşfedilmesi ve bunlar arasında bir bağıntının çıkarılması güç olabilmektedir. Böyle durumlarda sezgisel yöntemler birçok zaman iyi sonuç verebilmektedir. Özellikle parametre sayısının fazla ve doğrusal olmadığı problemlerde sezgisel yöntemler çözüme gitmeyi kolaylaştırabilmektedir.

Yapay afterimage algoritması literatüre yeni kazandırılan bir sezgisel algoritmadır. Bu yönüyle farklı alanlardaki veriler üzerine uygulamaya açık bir yöntemdir. Yapılan çalışmalar göstermiştir ki; performans açısından iyi sonuçlar vermektedir. Özellikle kümeleme uygulamalarında literatürdeki çalışmalara yakın ve bazen literatürden daha iyi sonuçlar verdiği görülmüştür. Bu yönüyle diğer alanlarda da başarılı olma potansiyeli olma ihtimali yüksek bir yöntemdir.

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THE IMPACT OF LOCAL ARTIFICIAL INTELLIGENCE MODELS ON HIGH SCHOOL STUDENTS' EXAM PREPARATION PROCESS: AN EVALUATION ON TOKEN VELOCITY AND ACHIEVEMENT PERFORMANCE

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ABSTRACT

This study examines the efficiency of local (offline) open-source large language models (LLMs) in the Basic Proficiency Test (TYT) format, the first stage of Türkiye's Higher Education Institutions Examination (YKS). Experiments were conducted on a modest system equipped with an NVIDIA GTX 1650 GPU (4 GB VRAM) and an Intel Core i7-11370H processor. Models that achieved an inference speed of ≥ 7 tokens per second (Qwen-2.5, Qwen-3, and Gemma-3) were included; those below this threshold (e.g., the local 7 B version of DeepSeek-R1, which yielded only ~2–3 tokens per second) were excluded. As a reference, the cloud-based DeepSeek-R1 model with 671 B parameters displayed top-tier performance with an accuracy of 83.15 %. Among local models, Qwen-3 presented the most balanced results, with an average inference speed of 8.4 tokens per second and an accuracy of 66.31 %. The findings indicate that meaningful success can be achieved on 4 GB VRAM devices through proper quantization and prompt tuning. In light of these results, discussions address equal opportunity and the digital divide in educational technology, emphasizing the potential of local AI solutions for students in rural areas without internet access.

Keywords: local language models; token throughput; accuracy; educational technology; equal opportunity

1 Introduction

1.1. Background

The YKS–TYT is the first step of Türkiye's university entrance examination, taken annually by more than three million candidates. Insufficient internet infrastructure in rural regions restricts access to remote education and deepens educational inequity. Studies conducted during the 2020 pandemic revealed that at least 20 % of Turkish students lacked home internet access. This digital divide hampers the use of online resources and AI-based educational content. Locally deployed LLMs that require no internet connection can therefore offer a low-cost solution. However, balancing output speed and accuracy when running such models on resource-constrained devices is a significant engineering challenge. Although models with large parameter counts may yield better results, hardware limitations often necessitate smaller models. Consequently, it is essential to examine how accurately small models can answer educational questions while producing outputs fast enough to avoid user delay.

1.2 Research Objectives

The primary aim of this study is to comprehensively evaluate the performance of small-scale LLMs operating on a device with 4 GB VRAM on TYT-like questions. Accordingly, our objectives are:

- Measure the inference speed of LLMs within the 4 GB VRAM limit in tokens per second.
- Compare the success rates (accuracy percentages) of the same models on a 95-item TYT-like test.
- Quantitatively analyse performance differences between local models and the 671 B-parameter cloud reference model, DeepSeek-R1.
- Provide educational technology and pedagogical insights into the speed–accuracy trade-off based on the obtained findings.

2 Related Work

In recent years, parameter-efficient methods aimed at improving AI applications in low-resource environments have attracted significant attention. MobileBERT (Sun et al., 2020) compressed the classic BERT model by approximately 4.3× while preserving its information capacity, achieving competitive results on GLUE and SQuAD tasks with only a minor performance drop and running 5.5× faster—enabling real-time inference even on mobile devices. Subsequently, LoRA (Hu et al., 2021) reduced the number of trainable parameters by 10,000× compared with full fine-tuning by adding low-rank adaptation layers to large language models, cutting GPU memory requirements by one-third while attaining accuracy comparable to full-model training.

Quantization is among the most common techniques for increasing inference speed. The 4-bit quantization experiments applied to the LLaMA-2 model by Touvron et al. (2023) reduced memory usage during inference by 75 % and, with optimized GPU kernels, increased inference speed by up to 3×. This speed gain incurred less than a 20 % loss in accuracy (i.e., more than 80 % of the model's accuracy was retained). Recent studies likewise report that 4-bit-quantized LLMs perform near their full-precision counterparts. Notably, the Q4_K_M-based quantized versions of next-generation open models such as Qwen and Gemma demonstrate consistent performance on GPUs with 4 GB VRAM (Qwen Team, 2025; Google AI, 2024).

Although these techniques are promising, no comprehensive study has systematically addressed their impact on the speed–accuracy balance in a multi-disciplinary, high-stakes examination such as TYT. This paper fills that gap by providing a multifaceted analysis of how small-scale local LLMs answer TYT questions on resource-constrained hardware.

3 Materials and Methods

3.1 Hardware Configuration

The experiments were carried out on a standard laptop platform. The system's key hardware specifications are summarized in **Table 1**.

Table 1. Hardware specifications of the experimental environment

Component	Specification
GPU	NVIDIA GTX 1650 - 4 GB
CPU	11th Gen Intel® Core™ i7-11370H @ 3.30 GHz
RAM	16 GB DDR4-3200
Storage	512 GB NVMe SSD
Operating System	Windows 10 Pro (64-bit)
Drivers	CUDA 12.3, cuDNN 9.0

Compared with today's high-end gaming or workstation setups, this configuration is modest. In particular, the 4 GB of VRAM imposes a severe constraint on LLM deployment, making substantial parameter compression (e.g., quantization) essential.

3.2 Software Framework

The software stack and tools employed in the study are listed below:

- **Ollama v0.9.0** – command-line interface for downloading and managing models in INT4/FP16 formats (GitHub, open source).
- **Docker Desktop v4.41** – container infrastructure for running models in an isolated environment (Docker Inc.).
- **OpenAI Web UI v0.6.13** – interface for model interaction and prompt analysis (GitHub, open source).
- **vLLM v0.9.0.1** – high-performance inference library and token-throughput meter (built with NVIDIA CUDA 12.8 and cuDNN 9.10.2; PyPI).

These tools handle low-level optimizations (e.g., deep-learning kernels), enabling us to focus exclusively on model outputs and performance metrics. In particular, **vLLM** proved pivotal for timing inference and managing GPU memory.

3.3 Dataset

For evaluation purposes, a TYT-style mock examination aligned with the Turkish Ministry of National Education (MEB) curriculum was employed to avoid any copyright issues. The original mock test comprised **120 questions**; because the model can process only text-based items, **25 questions containing visual content** (graphs, tables, diagrams) were excluded. The

remaining **95 questions** constituted the evaluation set. Their distribution by subject area is given in **Table 2**.

Table 2. Distribution of original and text-based TYT-like questions

Subject Area	Original (120 items)	Text-based (95 items)
Turkish	40	40
Social	20	20
Mathematics	40	23
Sciences	20	12

Each item is a five-option (A–E) multiple-choice question, balanced across the learning outcomes of the 2024 MEB curriculum and the knowledge–comprehension, analysis, and higher levels of Bloom's taxonomy. This structure ensures a fair assessment of text-based LLMs on both basic knowledge and higher-order reasoning tasks.

3 Materials and Methods

3.4 Model Pool and Pre-Screening

To identify the models for evaluation, a pool of popular open-source LLMs was first compiled. Using Ollama, the most-downloaded models on Hugging Face were scanned, and those expected to perform well on TYT-like tasks were shortlisted. Each model's token-generation speed on the test system was then measured. Preliminary user-experience surveys indicate that fluent interaction requires a minimum speed of 7 tokens per second (based on user polls) (r/LocalLLaMA, 2023). Consequently, models that failed to meet the ≥ 7 tokens per second threshold were eliminated. For example, the local 7 B-parameter version of DeepSeek-R1 achieved only 1.9–3.1 tokens per second and was excluded. Three models advanced to the final stage: Qwen-2.5 (3 B), Qwen-3 (4 B), and Gemma-3 (4 B). These not only provided adequate speed but have also been reported as successful in recent literature. For comparison, the 671 B-parameter cloud model DeepSeek-R1, representing state-of-the-art performance, was included as a reference.

Qwen-2.5 and Qwen-3, developed by Alibaba Cloud, stand out for their multilingual capabilities and an enhanced reasoning feature known as "thinking mode." Gemma-3, derived from Google's Gemini project, is positioned as an efficiency-oriented open-weight model. Both families were released under open licences in 2024–2025. Qwen-3 supports a Mixture-of-Experts (MoE) architecture and performs strongly in over 100 languages, whereas Gemma-3 excels with multimodal support and a long context window (up to 128 K tokens).

3.4.1 Model Quantization and Memory Requirements

To run on limited VRAM, all selected models were loaded in the Q4_K_M quantization format, which stores weights as 4-bit integers while preserving accuracy by separately retaining certain distribution moments. **Table 3** summarizes each model's parameters and memory footprint.

Table 3. Memory usage of quantized models

Model	Parameter Count	Quantization	Memory Requirement
Gemma-3	4.3 B	Q4_K_M	3.3 GB
Qwen-3	4.02 B	Q4_K_M	2.6 GB
Qwen-2.5	3.09 B	Q4_K_M	1.9 GB
DeepSeek-R1 (cloud)	671 B	Q4_K_M	404 GB

These figures represent the size of each model's weight file after quantization. Because a 671 B-parameter model would require roughly 400 GB of GPU memory even in Q4_K_M format, DeepSeek-R1 was accessed via a cloud server, whereas the other three models fit within 4 GB VRAM.

3.5 Evaluation Procedure

The models were assessed on the 95-item test set through the steps below:

1. Token-Throughput Measurement: Using vLLM's timing tools, the average number of tokens each model produced per second while answering the questions was logged. Total tokens generated were divided by total inference time to obtain mean tokens per second.
2. Accuracy Assessment: Models were prompted to output a single letter (A–E) for each question. Outputs were compared with the answer key and coded as correct or incorrect. Where necessary, answer templates (e.g., "Answer: B") were included in the prompts to ensure consistent formatting.
3. Statistical Analysis: A two-way ANOVA was conducted with Model (Qwen-2.5, Qwen-3, Gemma-3, DeepSeek-R1) and Subject Area (Turkish, Social Sciences, Mathematics, Natural Sciences) as factors, at a significance level of $\alpha = 0.05$. The analysis tested for performance differences across subject areas and for Model × Area interactions; significant effects were further examined with post-hoc tests.

4. Findings

4.1 Overall Performance

The general performance metrics of the three screened local models and the reference cloud model are summarized in **Table 4**. For each model, the parameter size, average token-generation speed, number of correct and incorrect answers, and overall accuracy percentage are reported.

Table 4. Overall accuracy and speed performance of the models

Model	Parameters (B)	Tokens/s	Correct	Incorrect	Accuracy (%)
Qwen-3	4	8.4	63	32	66.31
Gemma-3	4	7.9	49	46	51.57
Qwen-2.5	3	11.2	26	69	27.36
DeepSeek-R1 (cloud)	671	–	79	16	83.15

As shown in **Table 4**, the cloud-based DeepSeek-R1 model achieved the best result with 83.15 % accuracy. Among local models, Qwen-3 ranked first with an accuracy of 66.31 %, followed by Gemma-3 with 51.57 %. Qwen-2.5 performed markedly worse, reaching only 27.36 % accuracy. Qwen-3 answered 63 of the 95 questions correctly, while Gemma-3 answered 49 and Qwen-2.5 only 26.

Regarding speed, the smaller-parameter Qwen-2.5 was the fastest (11.2 t/s), followed by Qwen-3 (8.4 t/s) and Gemma-3 (7.9 t/s). Although Qwen-2.5 enjoyed a speed advantage—possibly owing to its lower parameter count and more aggressive optimizations—this did not translate into higher accuracy. On the contrary, it was the least accurate model, clearly illustrating the speed–accuracy trade-off: the fastest model produced the fewest correct answers. Qwen-3, in contrast, reached the highest accuracy while still operating within an acceptable speed range, indicating a more balanced position on this trade-off.

4.2 Sub-Test Analysis

To deepen the overall findings, accuracy was also calculated per subject area (Turkish, Social Sciences, Mathematics, Natural Sciences). Table 5 presents the percentage accuracy of each model for each area.

Table 5. Accuracy percentages of the models by sub-test

Subject Area	Qwen-2.5	Qwen-3	Gemma-3	DeepSeek-R1 (cloud)
Turkish	24 %	71 %	63 %	88 %
Social Sciences	31 %	69 %	48 %	74 %
Mathematics	18 %	34 %	22 %	30 %
Natural Sciences	36 %	61 %	55 %	78 %

The table shows substantial fluctuations across subject areas. For example, in the Turkish section, Qwen-3 achieved a strong 71 % accuracy, whereas Qwen-2.5 reached only 24 %. Likewise, Qwen-3 scored 69 % in Social Sciences, while Gemma-3 achieved 48 %. In Natural Sciences, Qwen-3 (61 %) and Gemma-3 (55 %) clearly outperformed Qwen-2.5 (36 %). A notable observation is the universally low performance in Mathematics: even Qwen-3 achieved only 34 % accuracy, and the cloud-based DeepSeek-R1 reached merely 30 % **(Figure 1)**. This suggests that the numerically intensive reasoning required by these tasks is challenging for both small and large models.

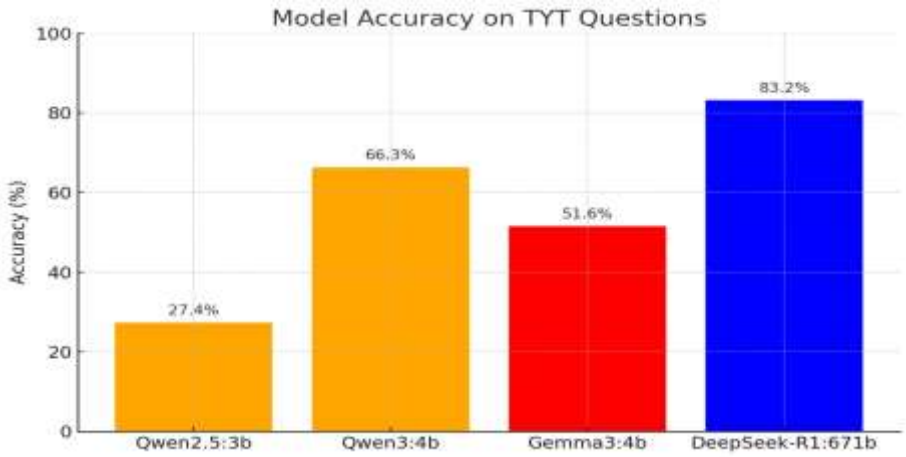


Figure 1. Model Accuracy on TYT Questions

A two-way ANOVA revealed that the main effects of Model and Subject Area, as well as their Model × Area interaction, were statistically significant ($F(3, 12) = 6.12$, $p < 0.01$). This indicates that performance differences between models are not uniform across subject areas; a model's superiority over another depends on the specific section. For instance, while the gap between Qwen-3 and DeepSeek-R1 is narrow in Mathematics (~4 %), DeepSeek-R1 outperforms Qwen-3 by about 17 % in the Turkish section. The significant interaction suggests that future work should target architecture-specific weaknesses within particular subject areas for tailored improvements.

4.3 Evolutionary Trajectory of Model Scale: The Emergence of "Small but Successful" Models

The findings obtained align with a major trend observed in artificial intelligence in recent years: it has become feasible to achieve high performance with "small" models containing comparatively few parameters. This section discusses two main developments in the literature that account for the relative success of such models: (i) breakthroughs in data and training strategies and (ii) architectural and inference-time optimizations.

1- Compute-optimal training approach. Introduced in 2022, the Chinchilla principle demonstrated that there exists a compute-optimal point that balances model size and the amount of training data. In essence, adding parameters does not always translate into higher performance; what matters is training the model with high-quality data in proportion to its parameter count. For example, the 70-billion-parameter Chinchilla model—which was trained on hundreds of billions of tokens—outperformed the 280-billion-parameter Gopher model by more than seven percentage points in average accuracy. This result proved that models trained with roughly twenty tokens per parameter can surpass enormous yet under-trained counterparts, thereby offering more efficient training strategies for researchers limited by hardware constraints.

2- Use of high-quality and synthetic data. Another factor enhancing the success of small models is their training on far higher-quality data. Rather than relying on random internet text, recent models are fine-tuned on textbook-level, human-curated corpora and even synthetic data generated by stronger models. Consequently, even with few

parameters, the knowledge and patterns a model acquires become markedly richer. For instance, the 13-billion-parameter Vicuna model - fine-tuned on ChatGPT dialogues shared by users - has reached 90 % of ChatGPT's response quality (Vicuna Team, 2023). Similarly, Meta's Alpaca and its derivatives, trained on instruction–response pairs produced by GPT-3.5/GPT-4, have attained much higher performance than initially expected. These developments indicate that training a small model under the guidance of a larger one (via distillation or reinforcement) effectively endows it with the "knowledge of the large model," raising the performance ceiling of small models day by day.

In addition to these factors, architectural and inference-time optimizations—such as quantization and LoRA—have been applied to small models, enabling real-time operation. For example, the Q4_K_M quantization format employed in this study reduces model size while minimizing accuracy loss (Brown, 2022). Moreover, infrastructures such as vLLM lower inference latency through techniques like batching and caching. Taken together, these advances make it possible to achieve high performance on specific tasks with "small yet fast" models: when the entire pipeline from training to inference is designed efficiently, even an LLM running on a device with 4 GB of VRAM can correctly answer the majority of high-school-level exam questions.

5. Discussion

The findings of this study indicate that small language models running locally can serve as educational support tools under certain conditions. The Qwen-3 model, which achieved a 66 % accuracy rate, demonstrated performance very close to that of the powerful cloud-based model, particularly in the domains of Turkish language and Social Sciences. This suggests that students could practice exam questions with an AI assistant on their own devices—even without internet access. Conversely, the low performance of all models in Mathematics reveals that questions requiring numerical and logical reasoning remain challenging for AI. This underscores the continued importance of teacher guidance and explicit explanation of solution steps. In other words, although LLMs can produce concise answers effectively, domains such as mathematics may still require larger models or specialized techniques for detailed, step-by-step explanations.

From a speed standpoint, evaluated from a user-experience perspective, the Qwen-3 and Gemma-3 models operate at approximately 8 tokens per second, which falls within an acceptable range. Although Qwen-2.5 offered higher throughput, its practical utility was limited by its lower accuracy. According to user surveys, a minimum speed of 7 tokens per second is required for a fluid conversational interface. Models that fall below this threshold (e.g., the excluded 7 billion-parameter model) introduce significant delays, prolonging students' wait times. Therefore, any locally deployed educational support application should employ a model that delivers both sufficient accuracy and at least this minimum speed; otherwise, students may lose focus or abandon the system while waiting for responses.

The results also carry implications for educational policy and technology integration. Establishing offline AI stations in rural or infrastructure-limited regions is a promising concept. For example, local LLMs hosted on a robust, on-premises server in a school could function as an AI tutor that students access sequentially or simultaneously. This would enable learners in disadvantaged areas to engage in AI-supported education even without internet connectivity. Running large-scale language models locally—rather than on centralized cloud servers—also offers security and privacy benefits by keeping data on-site. Educational content and exam

questions can be answered directly within the classroom, without transmitting data externally. Such an approach could strengthen equity in access to digital learning.

Moreover, local LLM deployment is unlikely to diminish teachers' roles; rather, by relieving them of repetitive tasks (e.g., grading tests, providing basic feedback), it could free up time for pedagogical guidance and motivational support. From a pedagogical perspective, it is essential that students maintain critical thinking skills and consistently verify the accuracy of model outputs. Because models can err, students should be encouraged to identify mistakes and analyse their causes. Doing so can become part of the learning process itself—for instance, discussing "Why might the AI have answered this question incorrectly?" can uncover conceptual misunderstandings. In conclusion, when properly integrated, local LLMs can augment traditional educational approaches and serve as valuable supportive tools.

6. Conclusion and Recommendations

In this study, the success of locally running language models on a device with limited hardware capacity was examined for answering university entrance–level questions. The results show that, with the appropriate choice of model and optimizations, offline models can operate with reasonable accuracy and speed. In light of these findings, the key conclusions and recommendations can be summarized as follows:

- Best Local Model: Under a 4 GB VRAM constraint, the Qwen-3 (4 B, Q4_K_M) model offered the best balance, achieving 66 % accuracy and approximately 8 tokens per second. This model is recommended as the most suitable local model for educational support under the conditions examined.
- Hybrid Deployment: Although powerful cloud-based models (e.g., DeepSeek-R1 or GPT-4) deliver higher performance in verbally oriented subjects (Turkish, Social Sciences), the performance gap between cloud and local models narrows in quantitative subjects (Mathematics, Science). Therefore, a hybrid approach using a cloud model for verbal questions and a local model for numerical questions may be both practical and cost-effective.
- Policy Recommendation: The establishment of offline AI learning centres in disadvantaged regions should be considered; this would enable students without Internet access to benefit from AI-supported educational tools. Such centres could host the necessary hardware and models in advance and serve students over a local network.

In conclusion, open-source local language models can be employed in education to promote equity of opportunity. Nevertheless, it should be kept in mind that large commercial models still offer superior performance. As research continues to enhance the quality of small models, offline AI assistants may become an integral component of future educational practices.

7. Conflict of Interest Statement

The authors declare that there are no institutional or financial conflicts of interest associated with this work.

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BEYOND SEQUENCING NODES: UNLOCKING THE PROFIT POTENTIAL OF VEHICLE ROUTING THROUGH PROACTIVE CUSTOMER ENGAGEMENT

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ABSTRACT

This paper explores how strategic customer engagement can significantly improve vehicle routing efficiency (by influencing the design of the routing set), particularly the demand-to-distance ratio. While existing routing algorithms excel at finding optimal routes for a given set of delivery points, they often overlook the crucial step of customer selection before all orders are finalized. Our study investigates the impact of distance- and demand-based customer selection after an initial set of orders has been placed. We utilized a well-established Hybrid Genetic Search (HGS) algorithm, specifically tailored for the Capacitated Vehicle Routing Problem (CVRP), to determine optimal routes across five distinct scenarios. These scenarios involved an initial random selection of 75 customers, followed by the addition of 50 more customers. The additional 50 were chosen based on different criteria: randomly, by highest demand, by shortest distance, or by the worst demand-over-distance ratio from the remaining pool of potential customers. Through one thousand simulated instances, our results consistently demonstrated that increasing the number of customers improved the demand-to-distance performance. Crucially, selecting customers based on their shortest distance exhibited a significantly steeper performance improvement compared to selection based solely on demand. This compelling evidence underscores that strategic customer addition plays a vital role in substantially enhancing vehicle routing efficiency.

Keywords: Traveling Salesman Problem (TSP), Capacitated Vehicle Routing Problem with Time Windows (CVRPTW), Revenue Management, Demand Responsiveness, Online Grocery, Urban Logistics.

Introduction

As a well and widely known fact reported multiple times through various studies, cities are globally under the pressure of rapidly increasing populations. By 2050, 68% of the world's population is projected to live in urban areas, which means our cities will have an additional 2.5 billion people to accommodate and provide sufficient urban spaces, while also facing the challenge of increasing motorization, according to the United Nations' famous report published in 2019 (Urbanization Statistics, Revision of World Urbanization Prospects., 2019).

Although its share in the total motorized urban trips reached to 40% in some cities already (Herzog, 2010), "urban logistics" has been nevertheless neglected for years while many policies and measures have been proposed and implemented (for public transport, electric vehicles, car-sharing and carpooling, cycling and walking, etc.) in the field of urban passenger mobility. Consequently, this has resulted in increasingly harmful effects (carbon emissions, traffic congestion, noise pollution, energy consumption) of freight vehicles in cities (Sebbane & Dablanc, 2019).

However, there are some fresh initiatives (full and hybrid human-powered vehicles, electric vehicles etc.) to address those passenger mobility problems mentioned above, "urban logistics" will remain as the most intense piece of "urban mobility" consuming the energy most per mile since it requires the use of large vehicles and the demand for the last-mile delivery is continuously increasing which is expected to increase 80% more than its current level today by 2030 (Brady-Phillips & Holmes, 2024, December).

Besides all the points mentioned above, some empirical studies of urban freight deliveries show that the average load factor of urban freight vehicles is only at 30-40% (which means more than half volumes of those vehicles are empty) and more than 20% of vehicles roam on roads of our cities full-empty (Letnik, Mencinger, & Božičnik, 2018), however, it is important to note that not all observable space within a vehicle means usable load capacity due to packaging, handling, stacking and time-slot etc., constraints in logistics operations. Although these studies measure idle space in freight vehicles, they often lack insight into the root causes and operational contexts, limiting their usefulness for developing targeted, domain-specific solutions.

To address the underutilization of load capacity in delivery (freight) vehicles, several land-use and demand management policies—such as time-based or vehicle-type-based access restrictions to streets/roads, and the collaborative/shared use of logistics resources among competitors (with or without shared consolidation centers or depots)—have been developed and implemented by public authorities at various levels (national, regional, or local). However, these efforts often fall short in prioritizing the commercial benefits of logistics service providers and tend to lack meaningful citizen engagement for collaborative solutions (Holguin-Veras, et al., 2021) (Dablanc, 2023). This gap is partly due to limited logistics-related knowledge within public administration institutions (Paddeu, 2025).

On the other hand, since the first introducing of Traveling Salesman Problem (TSP) (Cook, 2012) going back to almost 300 years ago from today and the generation of Vehicle Routing Problem (VRP) with its capacity constrained version (CVRP – Capacitated Vehicle Routing Problem) in 1959 as one of TSP's real-world reflections in the logistics domain (Dantzig & Ramser, 1959), its relatively younger sub-variant, born in the late 1980s (Solomon, 1987) (Kolen, Rinnooy Kan, & Trienekens, 1987), which also takes time windows constraints into account, called VRPTW (Vehicle Routing Problem with Time Windows), has been one of the topics studied less within the general VRP field – [or Traveling Salesman Problem With Profits

(TSPP) more generally] (Feillet, 2005), (Archetti, 2014), (Toth & Vigo, 2014), (Hameed, 2025).

While the majority of studies in this field has been focused on finding the shortest total route distance, beginning with the introducing of "dynamic pricing" approaches in 2007 (Figliozzi, 2007), some studies putted efforts to optimize slot assignments to delivery points (customers/recipients) in order to handle with (manage) uncertain demand observed in attended home delivery (AHD) operations (such as courier, express and parcel –CEP– and/or online grocery deliveries) as one of the real-world applications of CVRP(TW) (Klein, 2017), (Schwamberger, 2023) , (Abdollahi, 2023) , (Waßmuth, 2023).

Building on the previous studies mentioned above, and inspired by the fundamental principle of the Traveling Salesman Problem with Profits (TSPP) (Feillet, 2005) — where it is not necessary to visit all vertices and the operator (salesman) selects the most beneficial ones — this study explores broader strategic engagement opportunities between AHD operators and consumers during the stage of adding delivery points (vertices) to vehicle routes. The aim is to investigate whether there is meaningful potential for implementing engagement strategies to improve the overall efficiency of vehicle routing — CVRP(TW) in this study— operations by influencing the design of routing sets.

Materials and Methods

Material

The dataset used in this study is taken from CVRPLIB , a standard set of benchmark instances for the capacitated vehicle routing problem and publicly accessible at the following URL address http://vrp.galgos.inf.puc-rio.br/index.php/en (accessed on May 4th, 2025) (Uchoa, Pessoa, Poggi, Vidal, & Subramanian, 2017).

Rather than using the direct CVRPTW instances in the mentioned library, which are Solomon(1987) and Homberger & Gehring(1999), one set ('X-n214-k11') in one of the CVRP instances [Uchoa et al. (2014)] is preferred (selected) since only the characteristics of one single time-slot distribution is analyzed in this study by disregarding any hard and/or soft time windows priorities (requirements) of delivery nodes (points) in the problem set.

The CVRP dataset analyzed in this study is classified as "combined distribution" from the route organization aspect of e-commerce last-mile delivery operations (Winkenbach & Janjevic, 2018) and as "one-to-many distribution without transshipment" (Daganzo, 2005) within the Continuous (or Continuum) Approximation (CA) Models for Logistics and Transportation Systems (Ansari, Başdere, Li, Ouyang, & Smilowitz, 2018) and "with single echelon" by the operational chain-hierarchy angle (Clark & Scarf, 1960). The inventory aspect of the operation (inventory routing problem) (Dror, Ball, & Golden, 1985) is disregarded in order to preserve the simplicity of the problem. The problem does not include any reverse logistics transactions, either.

However there are variety of offered algorithms in the academic literature in order to get the shortest total distance within a CVRP problem (Hameed, 2025) , in this study a Hybrid Genetic Search (HGS) algorithm is selected which is introduced by (Vidal T. C., 2012) and (Vidal T. , 2022) based on its already proofed success at a competition organized in 2022 with multi judgment steps under the name of "The EURO meets NeurIPS 2022 Vehicle Routing Competition" (Kool, 2023). Simulations are carried out in a MATLAB environment.

Scenario – Method

In this study, an investigation is carried out to detect the impact of distance and demand-based customer selection after an initial set of orders has been placed. Within this purpose, a well-established Hybrid Genetic Search (HGS) algorithm, specifically tailored for the Capacitated Vehicle Routing Problem (CVRP) (as already mentioned above), is run to determine optimal routes across five distinct scenarios. These scenarios involved an initial random selection of 75 customers, followed by the addition of 50 more customers. The additional 50 were chosen based on different criteria: randomly, by highest demand, by shortest distance, or by the worst demand-over-distance ratio from the remaining pool of potential customers. For each scenario, one thousand simulations were carried out and the results were compared to each other among in total five distinct scenarios.

Findings and Discussion

Data in use

The dataset identified as 'X-n214-k11' comprises 214 coordinates, with the first denoting a depot location and the remaining 213 representing customer locations. Distances from the depot vary significantly, with the closest customer at 24.17 units and the furthest at 601.85 units, while the average distance stands at 291.44 units with a standard deviation of 129.75 units. Each customer has a fixed demand ranging from 2 to 100 units, averaging 48.62 units with a standard deviation of 29 units. This dataset also specifies a single vehicle with a demand fulfillment capacity of 944 units, strongly suggesting its application in a vehicle routing optimization context.

Algorithm in use

The problem was solved using a specialized version of the Hybrid Genetic Search (HGS) algorithm, as described by (Vidal T. C., 2012) and (Vidal T. , 2022), which is specifically tailored for the Capacitated Vehicle Routing Problem (CVRP). The modern implementation incorporates Advanced Diversity Control [https://github.com/vidalt/HGS-CVRP]. The only modification made to the default settings was decreasing the 'maximum number of iterations without improvement' to 1000. All coordinates from the dataset were included in the execution to identify the optimal routes that minimize total distance while using the necessary number of vehicles.

Solution for the data with all locations

The algorithm yielded a solution utilizing 11 vehicles to cover a total distance of 10,956 units. On average, each vehicle visited 19.36 locations with a standard deviation of 3.11, covering an average distance of 996.62 units with a standard deviation of 298.94. The depot, all customer locations, and the optimized vehicle routes are visualized in Fig. 1.

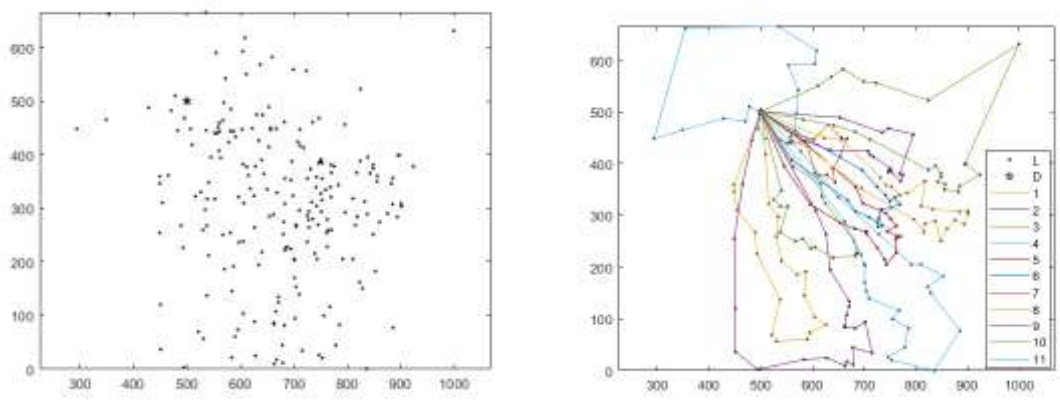


Figure 1. All locations of delivery points in the CVRP dataset used in this study (at the left) and the solution (best) routes gained by the algorithm (at the right).

Simulations

Following the methodology described in the previous section, 75 random customer locations were selected from the total of 213. The algorithm's solution for this scenario involved 4 vehicles traveling a total distance of 5233 units, successfully fulfilling the 3702 units of demand from these 75 customers. Consequently, the performance was calculated as a demand-to-distance ratio of 3702/5233 = 0.7074. The locations and vehicle routes are presented in Fig. 2.

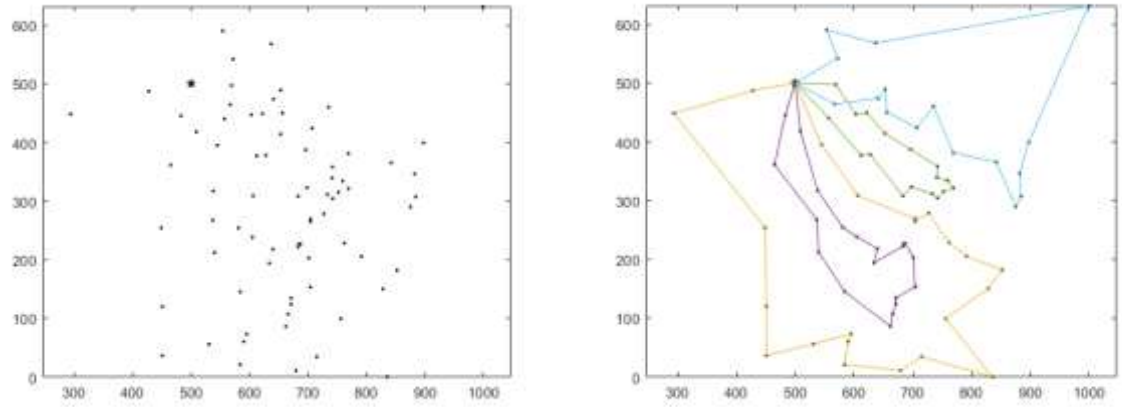


Figure 2. The locations of an instance with randomly selected initial 75 delivery points (at the left) and the solution (best) routes gained by the algorithm (at the right).

Starting with the initial 75 selected locations, an additional 50 random locations from the remaining pool were added as in Fig. 3, and the algorithm was executed. This resulted in a solution using 7 vehicles, covering 7395 units of distance, and satisfying 6375 units of demand. Notably, the performance, measured as the demand-to-distance ratio, increased to 0.8621 (6375/7395). Subsequently, instead of random selection, the 50 locations with the highest demand from the remaining pool were added to the initial 75, and the algorithm was executed again. This scenario required 9 vehicles, covered an increased distance of 8544 units, and fulfilled 7744 units of demand, leading to an improved performance ratio of 0.91 (7744/8544). The locations and vehicle routes are presented in Fig 4.

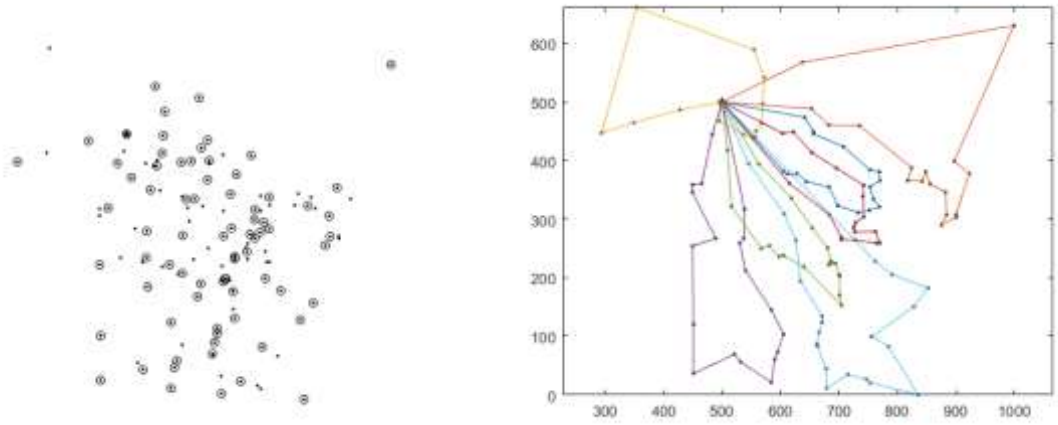


Figure 3. The locations of the same instance together with **randomly selected** additional 50 delivery points (at the left) and the solution (best) routes gained by the algorithm (at the right).

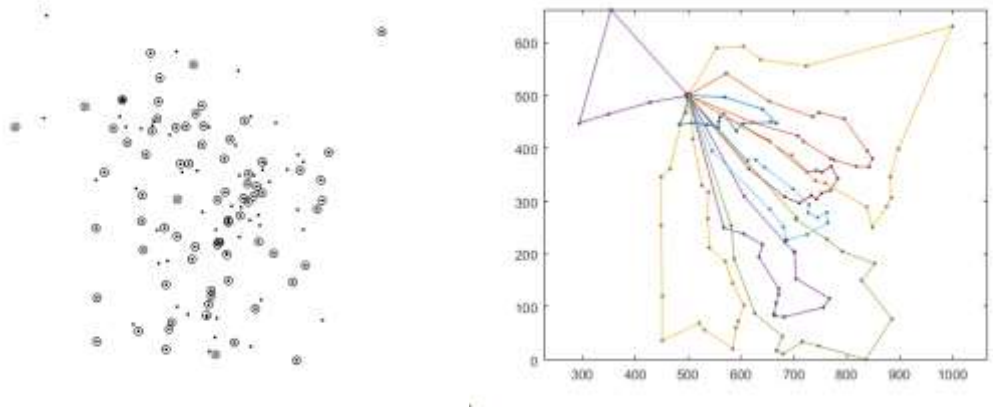


Figure 4. The locations of the same instance together with additional 50 delivery points selected by **highest demands** (at the left) and the solution (best) routes gained by the algorithm (at the right).

In an alternative selection method, another 50 locations were chosen from the remaining pool based on their proximity to the existing 75 locations as shown in Fig. 5. This resulted in 7 vehicles covering a distance of 7128 units and satisfying 6381 units of demand, with a resultant performance ratio of 0.8952 (6381/7128). Across all scenarios—whether the 50 additional customers were selected by demand, proximity, or randomly—an increase in performance was consistently observed.

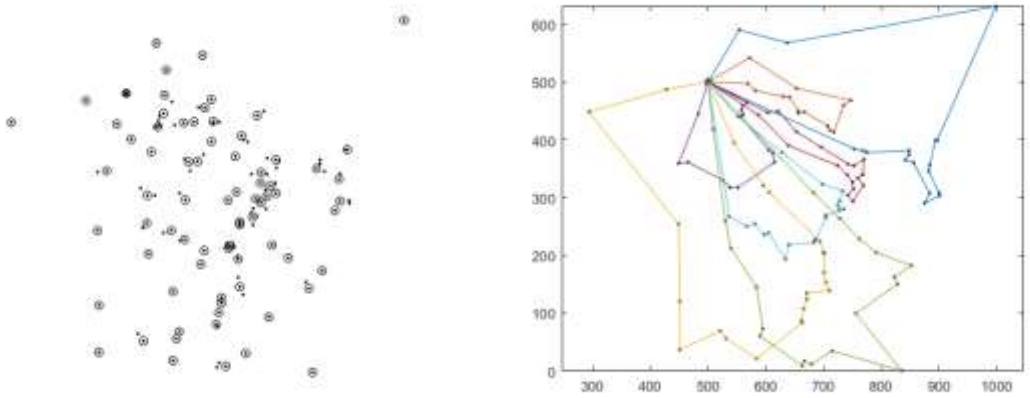


Figure 5. The locations of the same instance together with additional 50 delivery points selected by **shortest distances** (at the left) and the solution (best) routes gained by the algorithm (at the right).

Finally, when the 50 additional customers were selected based on a low demand/distance ratio as in Fig 6., the algorithm's solution resulted in a performance of 0.69. This outcome was falling behind the scenario that included only the initial 75 customers.

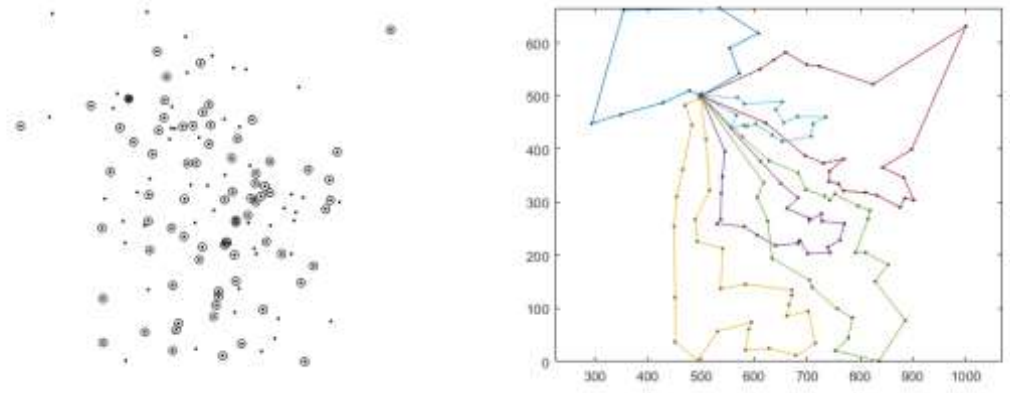


Figure 6. The locations of the same instance together with additional 50 delivery points selected by lowest demand/distance ratios (at the left) and the solution (best) routes gained by the algorithm (at the right).

Looking at the results presented so far, it can be inferred that increasing the number of customers (from 75 to 125) can improve the demand/distance performance. However, these results were derived from single instances. To increase the sample size and observe how adding customers impacts performance, the above simulation was repeated 1000 times. The performance results are presented in Fig. 7.

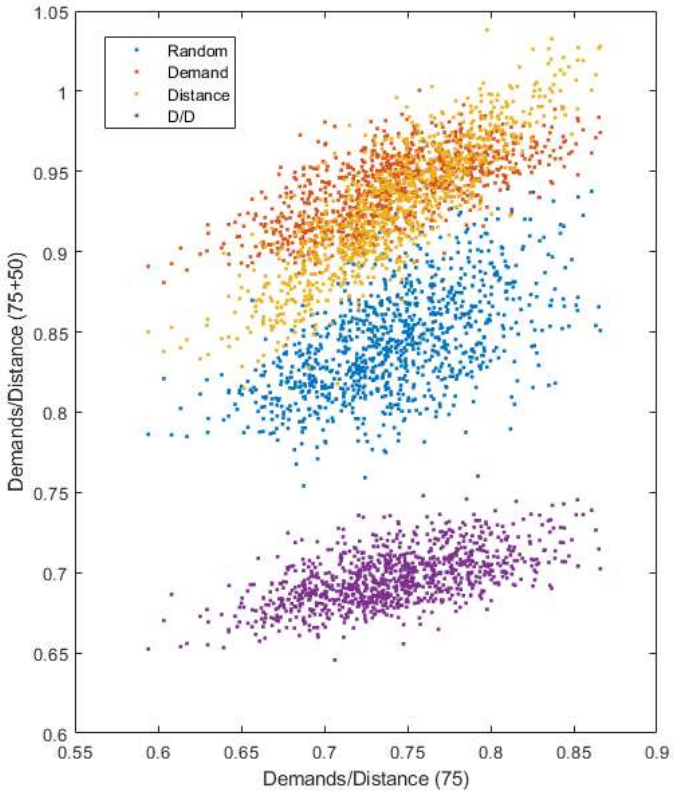


Figure 7. The efficiency change based on additional delivery points (horizontal axis – initial efficiencies, vertical axis – efficiencies after 50 additional costumers inserted).

In Fig. 7, the blue dots indicate that performance increases when an additional 50 customers are randomly selected. For each instance in the simulation, the initial 75 locations were randomly chosen, leading to a performance range distributed between 0.6 and 0.85. When 50 random locations are added to these initial customer sets, the figure shows a linear region where the performance range expands to 0.75-0.9. Adding 50 high-demand locations further boosted performance by 0.1. Similarly, selecting locations based on shortest distance also increased performance, with a noticeably steeper improvement trend compared to demand-based selection. For instance, an initial performance of 0.6 for 75 customers can rise to 0.85 with distance-based selection of 50 locations, while an initial performance of 0.85 can exceed 1.0 with the addition of more customers.

On the other hand, as a possible negative scenario, when customers with low demand-to-distance ratios were added, a decline in efficiency was observed. Initially, the efficiency ranged between 0.6 and 0.7, and after adding these customers, the resulting efficiency settled between 0.65 and 0.7. However, it was noted that experiments with an initial efficiency above 0.7 remained around the 0.7 level after adding additional customers.

Conclusion and Recommendations

In this study, the impact of distance and demand-based customer selection/engagement on the operation efficiency were investigated. The assessment involved an initial random selection of 75 customers, followed by the addition of 50 more customers based on different four criteria: randomly, by highest demand, by shortest distance, or by the worst demand-over-distance ratio from the remaining pool of potential customers. When 50 additional customers were randomly selected, an increase in efficiency was observed, indicating that serving more customers can have a positive impact on overall efficiency. Furthermore, the efficiency improved even more when the additional customers were selected from the pool based on high demand or low distance. However, it can also be concluded that choosing the wrong criterion for customer engagement may negatively affect efficiency.

As clearly indicated by the simulation outputs (particularly in Fig. 7), there is a significant positive difference between the fully random selection of vehicle routing vertices (nodes) and the two strategic approaches prioritizing either high-demand or short-distance vertices. This difference highlights meaningful potential for AHD operators to implement customer engagement strategies through incentivization mechanisms, aiming to enhance the overall profitability and efficiency of CVRP(TW) operations. Further optimization of these customer engagement strategies—addressing key questions such as “Which strategy or combination of strategies should be applied, in what ratio, and when, to influence recipient (delivery point) selection?”—represents a promising direction for future research involving additional simulation studies.

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COMPARATIVE ANALYSIS OF GAN-BASED TEXT-TO-IMAGE MODELS AND PROPOSAL OF A MODIFIED GALIP ARCHITECTURE

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ABSTRACT

AI-Generated Content (AIGC) refers to the creation of content such as text, images, audio, video, or code through artificial intelligence tools. These contents are produced based on prompts provided by users and are utilized in diverse domains including education, art, and healthcare. Among AIGC applications, text-to-image synthesis holds a significant position. Generative models developed for this task can be broadly categorized into three main groups: Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and Diffusion Models. The aim of this study is to examine the datasets used in text-to-image synthesis, the generative models employed, their architectural structures, loss functions, and mathematical foundations. In this work, the CUB-200-2011 (birds) dataset was used for training and evaluation. Although larger datasets such as COCO are commonly used in the literature, training text-to-image models requires high computational power and large VRAM capacities. Therefore, the birds' dataset was considered a more suitable choice for this study. The models used in the experiments include Attentional GAN, Deep Fusion GAN, Generative Adversarial Contrastive Language–Image Pretraining (GALIP), and a newly proposed GALIP variant with architectural modifications. These models were trained in a semi-scratch manner, where pretrained text encoders were kept frozen. Model performance was evaluated using metrics such as Frechet Inception Distance (FID) and Contrastive Language–Image Pretraining Score (CLIPScore). Experimental results show that the original GALIP model achieved 11.1302 FID and 0.3247 CLIPScore, whereas the proposed GALIP variant outperformed it with 10.8963 FID and 0.3254 CLIPScore. This study presents a comprehensive analysis of existing models' design principles and mathematical foundations, while also introducing a competitive GALIP-based variant that delivers better synthesis performance under limited computational resources.

Keywords: Text-to-Image Synthesis, Generative Adversarial Network, Generative Adversarial CLIP, Deep Fusion Generative Adversarial Network, Attentional Generative Adversarial Network

Introduction

Humans have always been able to transport objects and travel from one place to another using their bodies. What, then, was the purpose of inventing the wheel? It was, of course, the desire to do what we already could, but faster and more efficiently. In this context, we find a common ground between the invention of the wheel and the Artificial Intelligence Generated Content (AIGC): speed and efficiency.

AIGC refers to the creation of written, visual, or auditory content for creative, educational, and many other applications by artificial intelligence (Zhang et al., 2023). Through generative AI, it is possible to produce text, images, audio, video, and code. With advancements in Natural Language Processing (NLP) and Computer Vision, AIGC has reached a level of proficiency where it can produce high-quality content that is nearly indistinguishable from that created by human writers, designers, and artists (Zhang et al., 2023).

The adage "A picture is worth a thousand words" highlights the power of visual communication. Although written text provides a precise and concise means of conveying information, visual media such as images often deliver a richer, more accurate, and easily interpretable representation, facilitating better understanding and communication (Agnese et al., 2020). Therefore, visual content generation holds a significant place within AIGC applications.

Specifically in the domain of image generation, we observe three primary model architectures for Text-to-Image (TTI) synthesis: Generative Adversarial Networks (GANs), Diffusion Models, and Autoregressive Models. Contemporary models like DALL-E, DALL-E 2, and Stable Diffusion are based on diffusion or autoregressive architectures. However, training these models currently demands large datasets, substantial computational power, and significant hardware resources. Although GAN models may not produce images as realistic as these counterparts, they remain an important image generation model due to their lower computational requirements, ability to be trained on smaller datasets, and high inference speed. Furthermore, in recent years, these models have been combined with large-scale models, making them more competitive in terms of performance (Zhang et al., 2023).

One such model that integrates GANs with large-scale models is Generative Adversarial CLIP (GALIP). In this model, Contrastive Language-Image Pre-Training (CLIP) is utilized as the text and image encoder (Zhang et al., 2023).

A primary challenge in this field is the fusion of textual and visual information to generate a semantically coherent image. Solutions developed to address this problem include label-conditioned GANs (cGANs) or models like Attentional GAN (AttnGAN), which use a word-image attention mechanism (Agnese et al., 2020). The main objective of these and similar TTI models is to appropriately combine text and image data to generate an image that aligns with the given prompt. While the AttnGAN model uses an attention mechanism to achieve this semantic alignment, the GALIP model applies an affine transformation within its DFBlock component to harmonize the two modalities. This establishes a more robust semantic bridge between the textual and visual representation spaces (Tao et al., 2022).

In this study, AttnGAN, Deep Fusion GAN (DF-GAN), GALIP, and representing various GAN-based models were compared in terms of their architectures, loss functions, and performance using Fréchet Inception Distance (FID) and Contrastive Language–Image Pretraining Score (CLIPScore) metrics. Furthermore, to improve semantic alignment in text-to-image generation and enhance image diversity, we propose a modified Deep Fusion Block (DFBlock) variant, which also contributes to better gradient propagation. Details of this variant are presented in the following section.

Materials and Methods

Dataset

The models were trained using the Caltech-UCSD Birds-200-2011 (CUB-200-2011) dataset, introduced by Wah et al. (2011). Created by the Caltech Vision Lab, this dataset comprises a total of 11,788 images across 200 different bird species, with each species being represented by approximately 60 images.

The dataset provides not only class labels but also rich descriptive information with fine-grained details. For each bird, it includes annotations for 15 distinct part locations, such as the eye, beak, wings, and tail. Furthermore, it contains 312 binary attributes (e.g., “does it have long wings?” or “is the bird’s nape blue?”) and bounding box coordinates that specify the location of the birds in the images.

Due to this rich annotation structure, CUB-200-2011 is widely used as an ideal benchmark dataset for both fine-grained classification tasks and for training generative models that require text-to-image synthesis.

Text to Image Models

To perform text-to-image generation, a variety of GAN-based models, such as AttnGAN, DF-GAN and GALIP, were utilized to explore different architectural approaches.

Vanilla Generative Adversarial Network (GAN): GANs have marked a significant milestone in the field of generative modeling, due to their unique ability to generate realistic and diverse samples (Zhou, 2023).

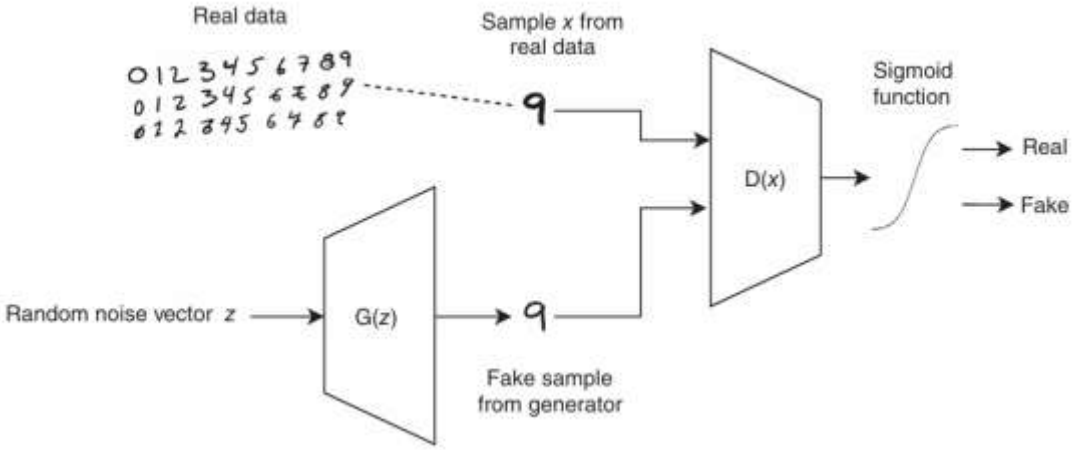


Figure 1. Vanilla GAN architecture (Agnese et al., 2020)

As illustrated in Figure 1, GANs are composed of two deep neural networks: a generator and a discriminator. The generator network takes a random noise vector as input and produces an image. This synthetic image is then fed to the discriminator. The objective of the generator is to create an image that the discriminator classifies as real. The discriminator network, on the other hand, receives both real images from the dataset and the synthetic images produced by the generator. The task of the discriminator is to correctly identify the generated images as fake and the real images as real (Agnese et al., 2020).

This architecture is trained through an optimization process based on game theory. The generator and discriminator have opposing objectives and compete in a zero-sum game. The loss function used in this adversarial process is defined as follows:

$$\min_G \max_D V(D,G) = \mathbb{E}_{x\sim p_{data(x)}}[log\, D(x)] + \mathbb{E}_{z\sim p_z(z)}\left[log\left(1 - D\big(G(z)\big)\right)\right] \quad (1)$$

Equation (1) introduces the key components of the GAN framework: the generator G aims to produce realistic samples, and the discriminator D attempts to distinguish between real data samples x and generated samples. The latent vector z provides the generator with a source of randomness, typically drawn from a standard normal distribution, which enables diverse data generation (Agnese et al., 2020). The discriminator's objective is to maximize the objective function. It aims to output a value of 1 for real images and 0 for synthetic images. In an optimal state for the discriminator, where its classifications are perfect, both terms in the objective function would approach *log(1)*, resulting in a value of 0. The generator, in turn, attempts to minimize its loss against the discriminator.

The vanilla GAN model represents a significant milestone for image generation. However, when considering a multi-class dataset such as the one used in this study, the problem of controlling which of the 200 bird species to generate becomes apparent. This leads to the question of how one can generate an image belonging to a specific class.

Conditional GAN (cGAN): This challenge was addressed by cGAN architecture, proposed by Mirza & Osindero (2014). As presented in Figure 2, in the cGAN model, both the generator and the discriminator are conditioned on extra information, such as class labels, which are provided as input in addition to the noise vector. Consequently, for the bird dataset specifically, the species of the bird in the generated image can be predetermined.

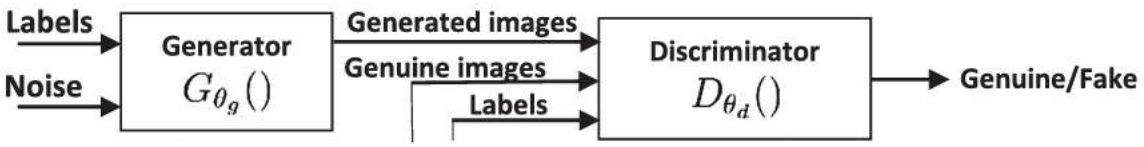


Figure 1. cGAN architecture (Agnese et al., 2020)

The loss function of the cGAN model is analogous to that of the Vanilla GAN. The primary distinction, however, is that the image generation and evaluation processes become conditional. The loss function, which is calculated based on the real/generated images given the corresponding label or condition, is then used to update the model's parameters during training.

$$\min_{\theta_g} \max_{\theta_d} V\left(D_{\theta_d}, E_{\theta_g}\right) = \mathbb{E}_{x\sim p_{data(x)}}\left[log\, D_{\theta_d}((x|y))\right] + \mathbb{E}_{z\sim p_{(z)}}\left[log\left(1 - D_{\theta_d}\left(G_{\theta_g}(z|y)\right)\right)\right] \quad (2)$$

The objective function of the cGAN is defined in Equation (2) which is very similar to the GAN objective function in Equation (1). D_{θ_d} denotes a discriminator function, controlled by parameters θ_d, which aims to classify a sample into a binary space. G_{θ_G} denotes a generator function, controlled by parameters θ_g, which aims to generate a sample from some latent space vector (Agnese et al., 2020).

In cGAN models, image generation is conditioned on class labels. However, generating an image of a specific bird species is often insufficient. For more granular control, more detailed visual attributes—such as the bird's color, the size of its body parts, and the surrounding environment—must also be taken into account.

Attentional Generative Adversarial Network (AttnGAN): In early TTI models, textual data was encoded into sentence vectors to generate images based on the input prompt. Although this method achieved impressive results, conditioning solely on a global sentence vector causes fine-grained, word-level details to be overlooked, thereby hindering the generation of high-quality images (Xu et al., 2018).

Another challenge inherent to GAN models is the risk of collapse in deep architectures. Due to their unstable nature, the backpropagation of gradients becomes more difficult as the network deepens. This can lead to issues such as gradient explosion or vanishing, resulting in mode collapse, which in turn impedes the construction of the deep architecture necessary for high-resolution image generation. To overcome this, the AttnGAN model utilizes 3-stage GAN architecture (Tao et al., 2022).

As illustrated in the figure, a given prompt is first processed by a Text Encoder, which utilizes a bi-directional LSTM, to extract both sentence and word features. The sentence features are concatenated with a random noise vector and fed into an Upsample block to generate initial image features. These features are then used by the generator for image synthesis and are also combined with the word vectors to be passed to the subsequent image generation stage. In the final generation stage, an Image Encoder extracts features from the produced image (Xu et al., 2018).

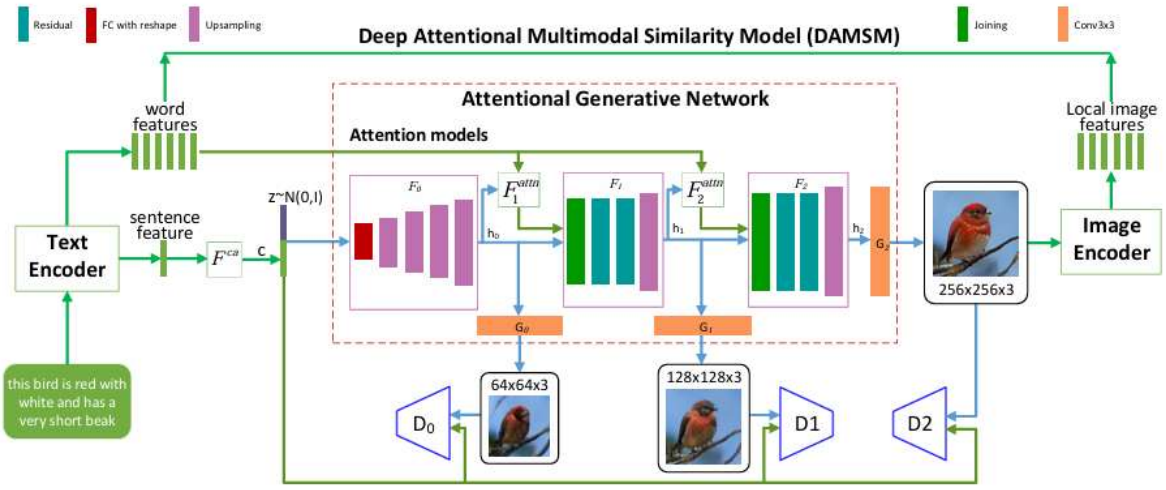


Figure 3. AttnGAN Architecture (Xu et al., 2018)

The semantic alignment is then calculated by comparing the word features from the Text Encoder with the image features using the Deep Attentional Multimodal Similarity (DAMSM) loss.

In Equation (3), the loss function of the AttnGAN architecture is comprised of the adversarial losses from the generator networks and the DAMSM loss, which is weighted by a coefficient, λ (Xu et al., 2018).

$$\mathcal{L} = \mathcal{L}_G + \lambda \mathcal{L}_{DAMSM}, where\ \mathcal{L}_G = \sum_{i=0}^{m-1} \mathcal{L}_{G_i} \quad (3)$$

In Equation (4) and (5), at the i^{th} stage of the AttnGAN the generator G_i paired with a discriminator D_i. Here, x_i samples drawn from the real image distribution p_{data_i} at scale i, while $\hat{x}^i$ denotes samples generated from the model distribution p_{G_i}at the corresponding scale

(Xu et al., 2018). The adversarial loss functions for the discriminator and generator are fundamentally similar to the objective function of the Vanilla GAN model. However, the total loss function in the AttnGAN model is composed of two parts: an unconditional component and a conditional component.

$$\mathcal{L}_{D_i} = \underbrace{-\frac{1}{2}\mathbb{E}_{x_i\sim p_{data_i}}[log\, D_i(x_i)] - \frac{1}{2}\mathbb{E}_{\hat{x}_i\sim p_{G_i}}\left[log\left(1 - D_i(\hat{x}_i)\right)\right]}_{unconditional\ loss}$$
$$\underbrace{-\frac{1}{2}\mathbb{E}_{x_i\sim p_{data_i}}[log\, D_i(x_i, \bar{e})] - \frac{1}{2}\mathbb{E}_{\hat{x}_i\sim p_{G_i}}\left[log\left(1 - D_i(\hat{x}_i, \bar{e})\right)\right]}_{conditional\ loss} \quad (4)$$

$$\mathcal{L}_{G_i} = \underbrace{-\frac{1}{2}\mathbb{E}_{\hat{x}_i\sim p_{G_i}}[log\, D_i(\hat{x}_i)]}_{unconditional\ loss} \underbrace{-\frac{1}{2}\mathbb{E}_{\hat{x}_i\sim p_{G_i}}[log\, D_i(\hat{x}_i, \bar{e})]}_{conditional\ loss} \quad (5)$$

While the unconditional loss focuses on classifying images as real or fake, the conditional loss ensures that the generated image accurately corresponds to the given textual description (Xu et al., 2018). The DAMSM loss, in turn, involves a bidirectional loss calculation at both the word and sentence levels.

$$\mathcal{L}_{DAMSM} = \mathcal{L}_1^{w} + \mathcal{L}_2^{w} + \mathcal{L}_1^{s} + \mathcal{L}_2^{s} \quad (6)$$

In equation (6), $\mathcal{L}_1^{w}$ checks the alignment between the i^{th} word vector and the j^{th} sub-region of the image. $\mathcal{L}_2^{w}$ computes the alignment between the i^{th} sub-region of the image and the j^{th} word vector. $\mathcal{L}_1^{s}$ and $\mathcal{L}_2^{s}$ control the bidirectional semantic consistency between the sentence and the image at the word and region levels (Xu et al., 2018).

Deep Fusion Generative Adversarial Network (DFGAN): Text-to-image synthesis is one of the most significant applications of GAN-based methods. This task aims to generate photorealistic and text-consistent images based on given natural language descriptions. Due to its high application potential, text-to-image synthesis has become an active area of research in recent years (Tao et al., 2022).

The two fundamental challenges in this domain are ensuring the realism of the generated images and maintaining semantic consistency between the given text and the image. Due to the inherent instability of GANs during training, stacked architectures, such as that in AttnGAN, are often preferred for high-resolution image generation. Additionally, attention mechanisms are employed to ensure semantic alignment. However, these solutions introduce a set of their own problems (Tao et al., 2022).

First, the stacked architecture creates entanglement between different generators, which often causes the final generated images to appear as a blurry shape with some crudely combined details. Second, existing methods typically fix the auxiliary networks (e.g., text or image encoders) during the adversarial training process. This allows the generator to easily fool these networks by producing adversarial features, thereby weakening the supervisory power of these networks in ensuring semantic consistency. Third, cross-modal attention mechanisms cannot fully leverage the textual information. Due to high computational costs, they can only be applied twice on image features of sizes 64×64 and 128×128. This limits the text-image fusion and hampers the model's scalability to higher-resolution image generation (Tao et al., 2022).

As a solution to the first problem, as demonstrated by Figure 4, the DF-GAN model introduces single-backbone architecture. Since the generator and discriminator networks are composed of deep models, residual blocks are utilized to facilitate learning by regulating the flow of

gradients. Furthermore, previous GAN models often faced a training problem where learning would stall if either the discriminator or the generator became significantly better than the other. To prevent this, hinge loss is employed (Tao et al., 2022).

$$\mathcal{L}_D = -\mathbb{E}_{x\sim\mathbb{P}_r}[min(0,-1+D(x,e)] - (1/2)\mathbb{E}_{G(z)\sim\mathbb{P}_g}\big[min\big(0,-1-D(G(z),e)\big)\big]$$
$$-(1/2)\mathbb{E}_{x\sim\mathbb{P}_{mis}}\big[min\big(0,-1-D(x,e)\big)\big] + k\mathbb{E}_{x\sim\mathbb{P}_r}[(\|\nabla_x D(x,e)\| + \|\nabla_x D(x,e)\|^p)] \quad (7)$$

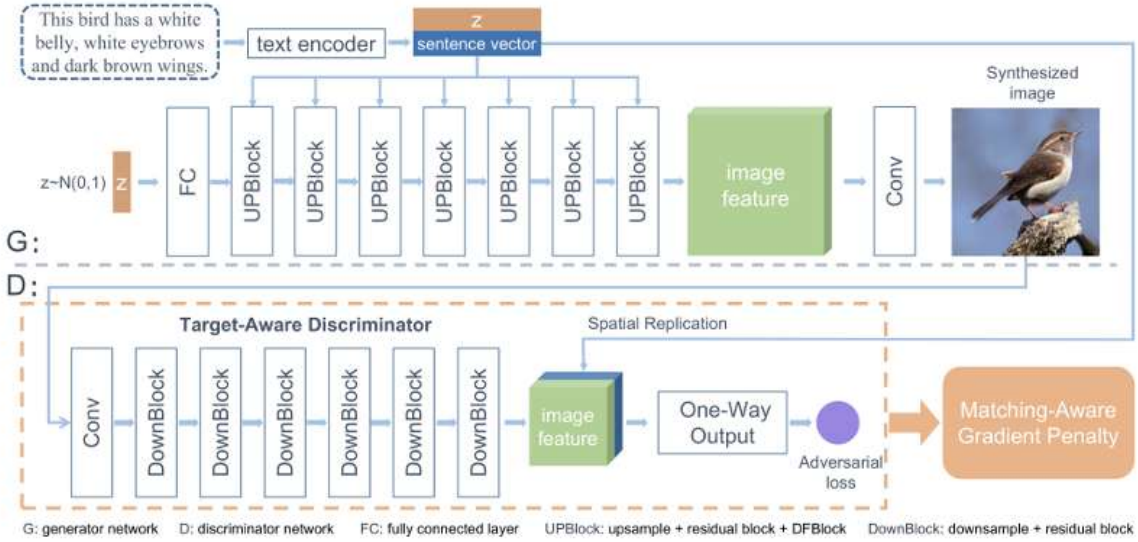


Figure 4. DF-GAN Architecture (Tao et al., 2022)

In equation (7), where z is the noise vector sampled from Gaussian distribution; e is the sentence vector; $\mathbb{P}_g, \mathbb{P}_r, \mathbb{P}_{mis}$ correspond to the distributions of generated data, real data, and mismatched data, respectively (Tao et al., 2022). To address the second problem, a Target-Aware Discriminator was designed to enhance text-image semantic consistency. It consists of two main components: Matching-Aware Gradient Penalty (MA-GP) and a One-Way Output (Tao et al., 2022).

$$\gamma = MLP_1(e), \quad \theta = MLP_2(e) \quad (8)$$

As illustrated in equation (8), the textual information is processed by two separate neural networks to generate scaling (γ) and shifting (β) parameters. In equation (9), these parameters are subsequently used to perform a channel-wise modulation of the visual features (Tao et al., 2022).

$$AFF(x_i|e) = \gamma_i . x_i + \theta_i \quad (9)$$

In conclusion, the DF-GAN model provides a remarkable baseline framework for the task of text-to-image synthesis, notable for both its architectural simplicity and semantic consistency.

Generative Adversarial CLIP (GALIP): Recent advancements in large-scale generative models have presented numerous opportunities for enhancing the performance of GAN-based TTI models (Zhang et al., 2023). One such GAN-based model is the GALIP model.

While impressive results in image generation are being achieved with large-scale datasets, massive model sizes, and pre-trained architectures like diffusion and autoregressive models, they still suffer from three fundamental weaknesses. First, the pre-training process for these models requires vast amounts of data and an enormous number of parameters. This leads to

high computational costs and demanding hardware requirements, making them inaccessible to many researchers and users. Second, the generation process of these large models is considerably slower compared to GANs. Token-based generation and progressive denoising procedures often require hundreds of inference steps, resulting in significant latency. Third, these models lack the intuitive and smooth latent space found in GANs, where meaningful visual attributes correspond to latent vectors. The multi-step generation process fragments the synthesis procedure and disrupts this coherent latent structure. Consequently, controlled image generation with these models necessitates carefully engineered prompts (Tao et al., 2023).

As illustrated in Figure 5, traditional GAN models fundamentally consist of a generator and a discriminator. The GALIP model, in contrast, integrates a pre-trained CLIP model with frozen weights. This integration enhances the model's ability to understand complex scenes and provides it with superior domain-generalization capabilities, owing to CLIP's large-scale pre-training (Tao et al., 2023).

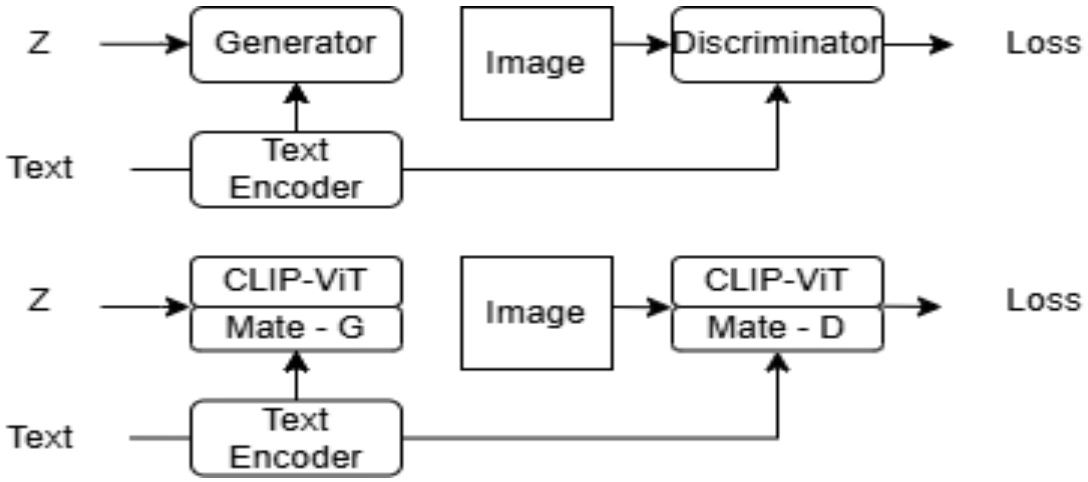


Figure 5. GAN and GALIP architecture (Tao et al., 2023)

As illustrated in Figure 6, the GALIP model is composed of three main components: Mate-G, Mate-D, and CLIP. The sentence vector T, generated by the text encoder, and a random noise vector Z are processed by a Bridge Feature Predictor to extract bridge features, which are then fed into the CLIP model. Subsequently, the output from the CLIP model is combined with Visual Concepts and passed to the Image Generator to synthesize the final image (Tao et al., 2023).

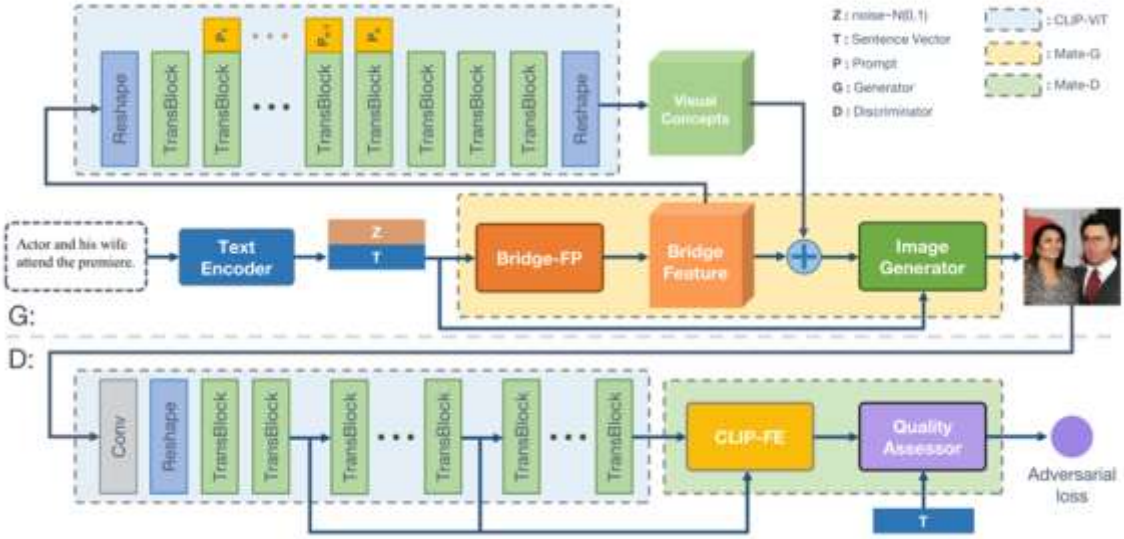


Figure 6. GALIP architecture (Tao et al., 2023)

As shown in Figure 7, From the generated image, features are extracted from different layers of the CLIP image encoder and fed to the CLIP-FE (CLIP Feature Extractor). These image features are then combined with the text data to calculate the adversarial loss (Tao et al., 2023).

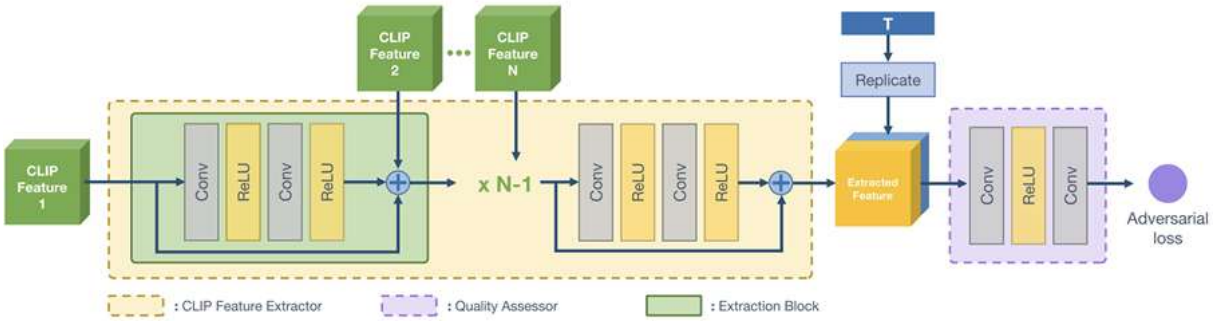


Figure 7. Mate-D (Tao et al., 2023)

As illustrated in Figure 8, we also observe the DF-Block structure in the CLIP Empowered Generator, which is used in the DF-GAN model for text-image semantic alignment, within the GALIP architecture. In this model, DFBlocks are utilized in both the Bridge Feature Predictor and the Image Generator components. In these stages, they work to ensure semantic alignment by fusing the sentence vector with visual features via an Affine transformation (Tao et al., 2023).

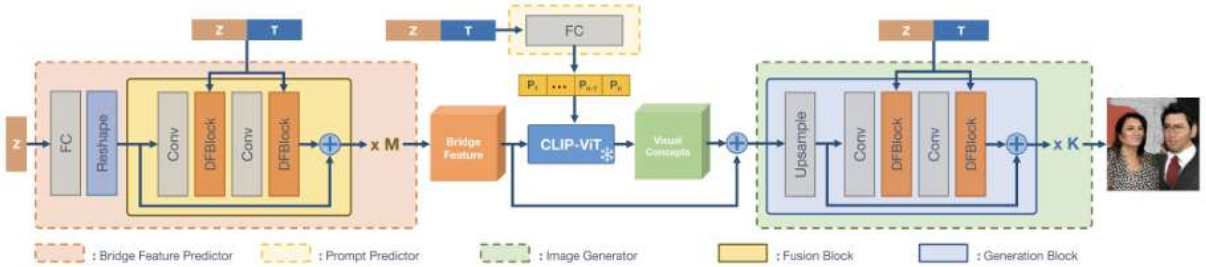


Figure 8. CLIP empowered Generator (Tao et al., 2023)

Proposed DFBlock: As depicted in Figure 9, the DFBlock structure is the key component for achieving text-image semantic alignment in both the DF-GAN and GALIP models. This

approach, noted for its higher efficiency compared to prior attention mechanisms, involves feeding the sentence vector into two distinct multi-layer neural networks. These networks subsequently output the scaling (γ) and shifting (β) parameters, as described in equation (8).

(Tao et al., 2022).

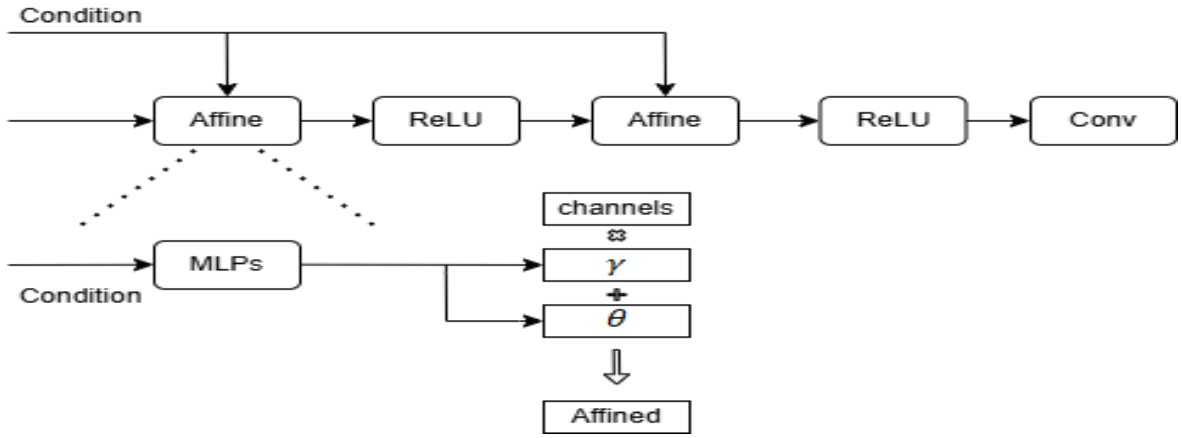


Figure 9. DFBlock (Tao et al., 2022)

These parameters are then applied to each channel of the visual features. In this way, the Affine layer expands the conditional representation space of the generator. However, the Affine transformation is an inherently linear operation for each channel, which limits the effectiveness of the text-image fusion process. Therefore, a ReLU layer is inserted between two Affine layers to introduce non-linearity into the fusion pipeline. This approach further expands the conditional representation space compared to using only a single Affine layer (Tao et al., 2022).

As illustrated in the Figure 10, the proposed new DFBlock structure includes an additional concatenation path alongside the original architecture. The sentence vector, with dimensions 32x512, is first compressed to 32x128. It then undergoes spatial replication before being concatenated with the visual feature vector. A 1x1 convolution is applied to adjust the channel dimension. Subsequently, the output matrices from the Affine path and the concatenation path are summed. The purpose of this concatenation is to increase diversity, supplementing the causal relationships learned between the text and image vectors in the Affine path. Furthermore, by making only slight modifications to the text and image vectors, a structure similar to a Residual Block is established, aiming to improve learning by enhancing the gradient flow.

Evaluation Metrics and Training Parameters: In this study, the FID and CLIPScore metrics were used for model performance evaluation. The FID metric measures how closely the distribution of generated images resembles the distribution of real images, providing insights into the realism and diversity of the generated content. Within this calculation, the covariance matrix quantifies the spread of features, thereby measuring diversity. A lower FID score is better. CLIPScore, on the other hand, indicates how semantically well a generated image matches a given text prompt. A higher CLIPScore signifies a better alignment between the image and the text (Zhang et al., 2023).

To compare the performance of the proposed DFBlock (containing both Affine and Concatenation paths) against the original DFBlock (containing only the Affine path), the models were trained using the hyperparameters shared in the official GitHub repository. The batch size was set to 32, and the training was conducted for 1502 epochs. The model was trained using both NVIDIA RTX 4070 Ti SUPER and NVIDIA A100 GPUs to assess performance across different hardware configurations.

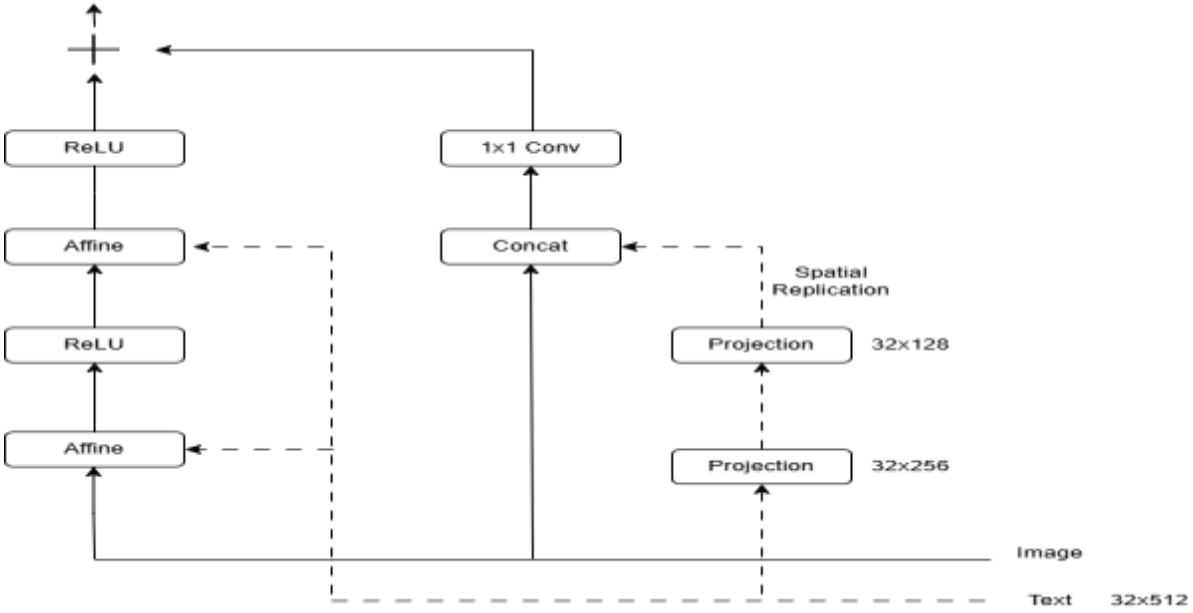


Figure 10. Proposed DFBlock

Results and Discussions

As shown in Table 1 and Figures 12-15, the GALIP models, featuring the original DFBlock and the proposed DFBlock respectively, were trained for 1502 epochs, with performance evaluations conducted every five epochs.

Table 1. Quantitative comparison of text-to-image models on the CUB-200-2011 dataset using FID (lower is better) and CLIPScore (higher is better).

Model	FID	Epoch (FID)	CLIPScore	Epoch (CLIPScore)
AttnGAN	23.98	-	29.4671	-
DF-GAN	11.5996	1150	28.9764	-
GALIP with proposed DFBlock	10.8963	680	0.3254	1435
GALIP with original DFBlock	11.1302	1420	0.3247	1500

Figures 11 through 14 present the best FID and CLIPScore values obtained during the training of the GALIP model with both the original and the proposed DFBlock. As shown in Figure 11, the proposed DFBlock achieved its optimal FID score of 10.8963 at epoch 680, whereas the original DFBlock reached a minimum FID of 11.1302 at epoch 1420 (Figure 12). Regarding semantic alignment, the model incorporating the proposed DFBlock attained the highest CLIPScore of 0.3254 at epoch 1435 (Figure 13), slightly outperforming the original DFBlock, which peaked at 0.3247 at epoch 1500 (Figure 14). These results indicate that the proposed modification not only enhances performance but also accelerates convergence during training.

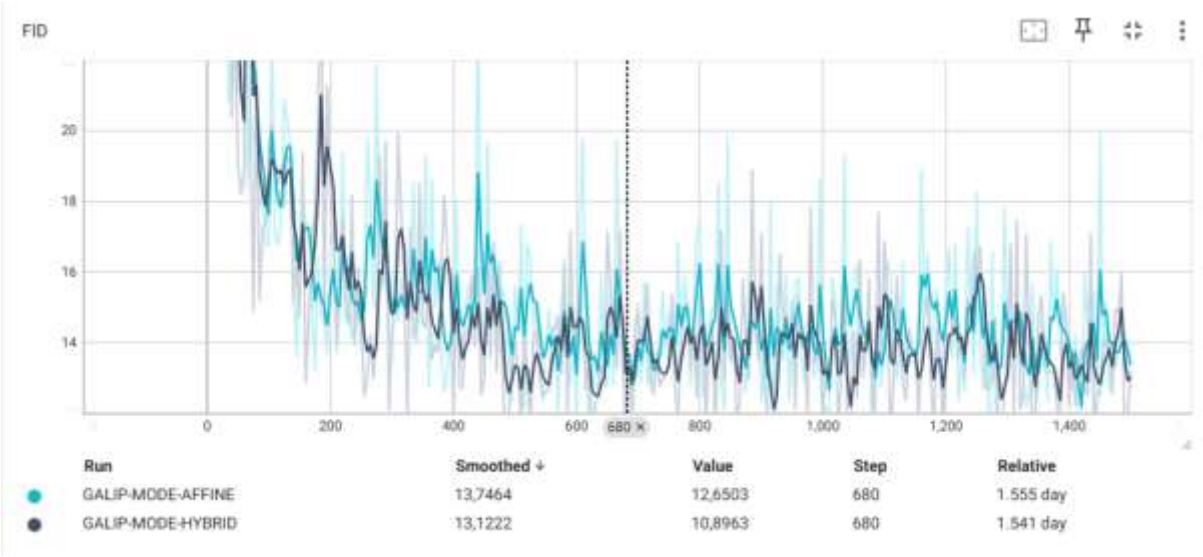


Figure 11. Best FID Score of GALIP with Proposed DFBlock

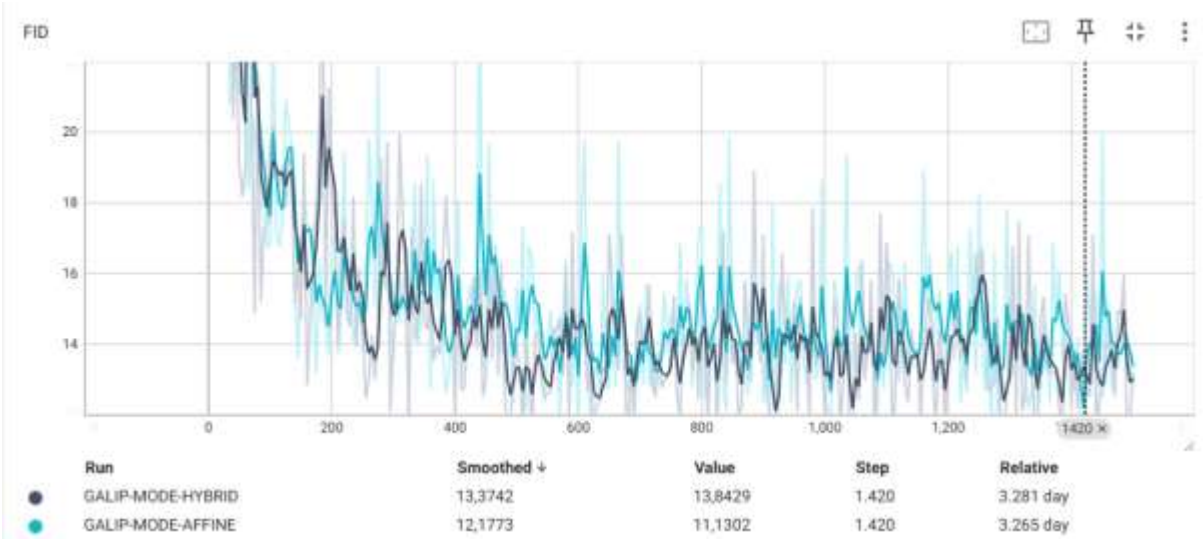


Figure 12. Best FID Score of GALIP with Original DFBlock

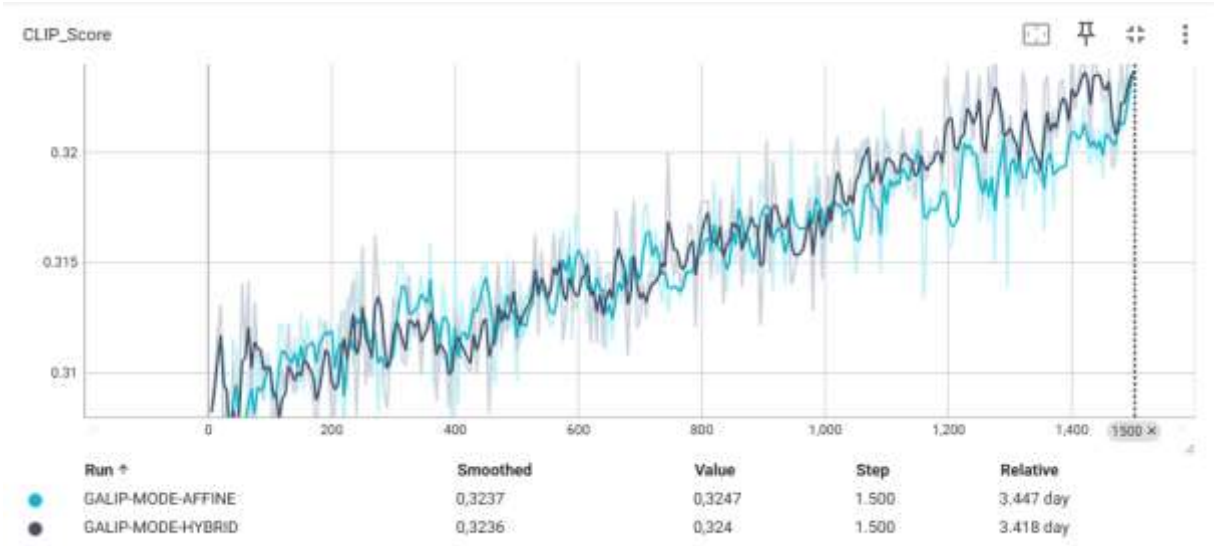


Figure 13. Best CLIPScore of GALIP with Proposed DFBlock

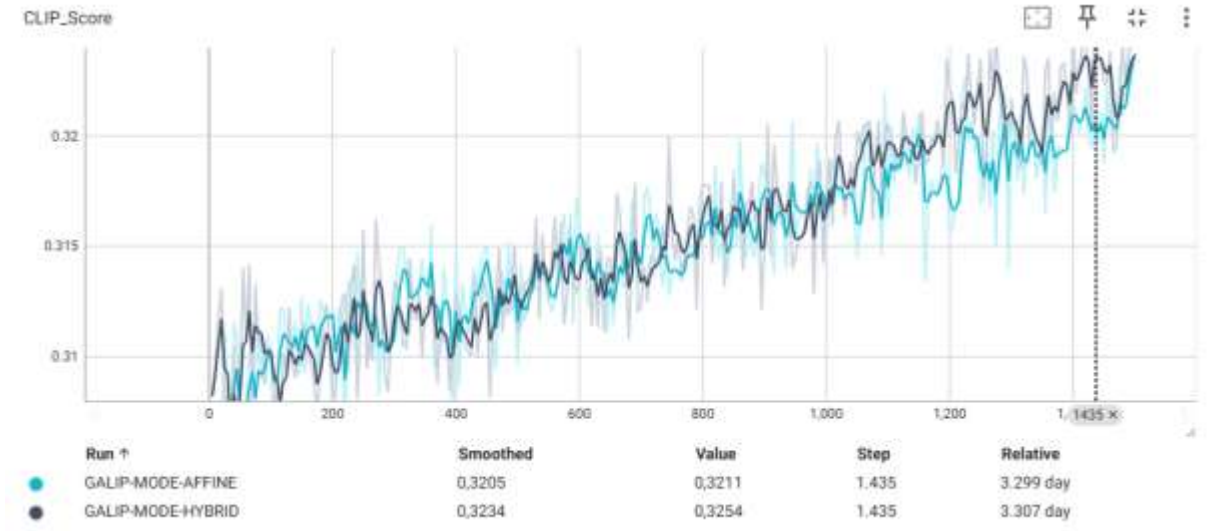


Figure 14. Best CLIPScore of GALIP with Original DFBlock

Conclusion

In this study, a comprehensive comparative analysis was conducted on GAN-based text-to-image synthesis models, including AttnGAN, DF-GAN, and GALIP. Furthermore, a modified version of the DFBlock component within the GALIP architecture was proposed to enhance semantic alignment and image diversity under limited computational resources. Specifically, the DFBlock was extended by introducing a concatenation path in parallel with the Affine branch, which also contributed to improved gradient propagation. Experimental results demonstrated that the proposed DFBlock yielded measurable improvements in both FID and CLIPScore metrics. Additionally, the modified model reached its optimal performance at significantly earlier epochs, indicating a faster convergence rate.

A key limitation of this study was the inability to evaluate the proposed method on the large-scale COCO dataset due to hardware constraints. Given that the baseline GALIP model has been reported to achieve notable FID and CLIPScore values when trained on COCO (Tao et al.,

2023), future research should focus on assessing the proposed DFBlock's performance and generalization capability on this benchmark dataset.

Acknowledgement

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INVESTIGATION OF BEAM COMPENSATIONON DIMENSIONAL ACCURACY OF A LPBF-MANUFACTURED Co–Cr ALLOY JET ENGINE COMPONENT

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ABSTRACT

Additive manufacturing via laser powder bed fusion (LPBF) has revolutionized the production of complex metal parts by enabling high geometric freedom and near-net-shape fabrication. Cobalt-chromium (Co-Cr) alloys, prized in aerospace for their exceptional high-temperature strength, oxidation and corrosion resistance, are increasingly adopted for LPBF fabrication of jet engine components. Although numerous LPBF parameters—such as laser power, scan speed, hatch speed, and layer thickness—can influence dimensional accuracy, beam compensation (BC) has substantial effect on the dimensions of the produced parts. This parameter defines an offset between the original slice contour and the outermost boundary to ensure the part is built to the correct dimensions. In this study, five identical Co–Cr jet engine components were printed under constant LPBF settings with only the BC value systematically varied (45-105 µm) between builds. Each as-built component was measured using a high-precision coordinate measuring machine (CMM) to quantify deviations from the nominal CAD geometry in critical features. Results show that the optimal BC setting yielded dimensional deviations of less than 1% on the inner diameter and under 0.6 % on the outer diameters, demonstrating high accuracy to the nominal design. These findings underscore the significant role of BC in achieving near-net-shape accuracy of LPBF-fabricated parts and provide practical guidelines for selecting compensation values that minimize post-process work.

Keywords: Additive manufacturing, laser powder bed fusion, Co-Cr alloys, dimensional accuracy

Introduction

In recent years, additive manufacturing (AM) technologies have gained significant attention for their ability to produce complex, lightweight, and high-performance components. Among these techniques, Laser Powder Bed Fusion (LPBF) has emerged as one of the most advanced methods, offering the capability to fabricate intricate metallic structures with excellent precision. In the LPBF process, a high-power laser selectively melts layers of metal powder based on a digital CAD model. After each laser scan, a fresh layer of powder is recoated, and this layer-by-layer approach continues until the entire part is fabricated. The LPBF process provides notable advantages, such as design flexibility, material efficiency, and the potential to reduce component mass—attributes that are critical in advanced engineering applications. (Yildiz & Babacan, 2024) (Aktürk et al., 2025)

Cobalt–Chromium–Molybdenum (Co–Cr–Mo) alloys are widely utilized in LPBF due to their exceptional high-temperature strength, superior wear and corrosion resistance, and excellent biocompatibility. These properties make Co–Cr–Mo alloys highly suitable for demanding applications in sectors such as aerospace, biomedical, and energy. The growing demand for lightweight and complex components has further driven interest in processing Co–Cr–Mo alloys through advanced AM techniques. (Acharya et al., 2021).

To ensure reliable processability in LPBF, Co–Cr–Mo alloy powders are typically produced via Vacuum Inert Gas Atomization (VIGA). This technique enables the production of powders with highly spherical morphology, uniform particle size distribution, and good chemical homogeneity — all of which are critical for maintaining stable powder flow and achieving consistent melting behavior during the LPBF process.

However, the mechanical properties, microstructure, and dimensional accuracy of LPBF-fabricated parts are affected by numerous LPBF process parameters, such as laser power, scanning speed, hatch distance, layer thickness, and scanning strategy. Among these factors, dimensional accuracy is particularly influenced by the offset between the laser scan path and the boundaries of the intended part geometry, which is governed by the melt pool geometry (Fig. 1a). This offset is controlled through the beam compensation (BC) (Fig. 1b), which helps to minimize dimensional deviations and improve the accuracy of the final part.

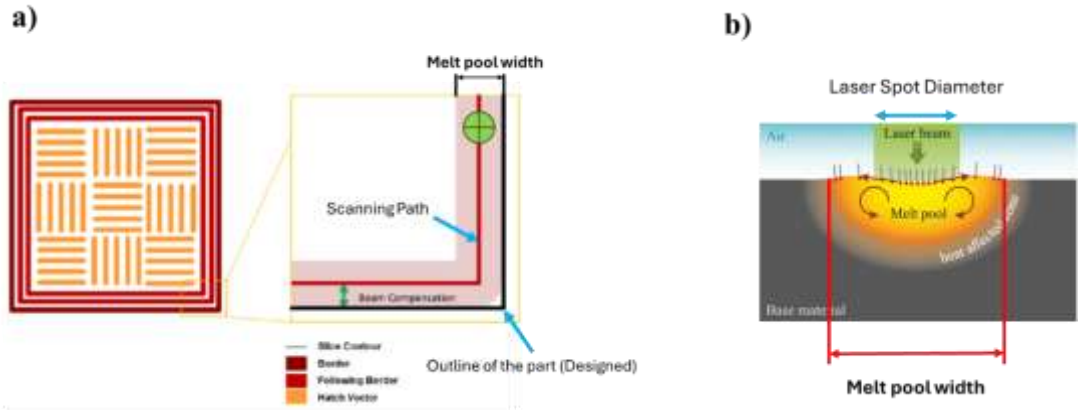


Figure 1. (a) Illustration of the BC; (b) Illustration of the melt pool boundary.

In this study, the effect of different BC settings on the dimensional accuracy of an aerospace jet engine component produced by LPBF from Co–Cr–Mo alloy powder was investigated. The findings aim to support the optimization of LPBF parameters for precision manufacturing of critical components in high-performance applications.

Materials and Methods

Co–Cr–Mo alloy powder with a spherical morphology was produced in-house via VIGA in compliance with the ASTM F75 standard. The powder was subsequently sieved to obtain a particle size range of 10–53 µm.

Five different jet engine components were fabricated using the LPBF (Ermaksan, EnaVision 130) process, employing 5 different BC parameters (45, 60, 75, 90, and 105 µm) under a nitrogen atmosphere. The following optimized process parameters were used during the production: laser power (180 W), scanning speed (581 mm/s), hatch distance (88 µm), layer thickness (30 µm), and laser spot diameter (75 µm). These parameters were chosen based on previous studies (Yıldız et al., 2023; Yıldız et al., 2025). A heat treatment was conducted at 750 °C for 2 hours to relieve internal stress and obtain suitable microstructure within the fabricated parts.

A Coordinate Measuring Machine (CMM) was used to measure five different diameters on each part, as the measurement locations illustrated in Fig. 2. Fig. 3 shows the setup and the CMM during the measurement process. After the measurements, the results were compared with the designed dimensions in terms of percentage deviation.



Figure 2. Measurement locations on the part surfaces (green-colored surfaces).

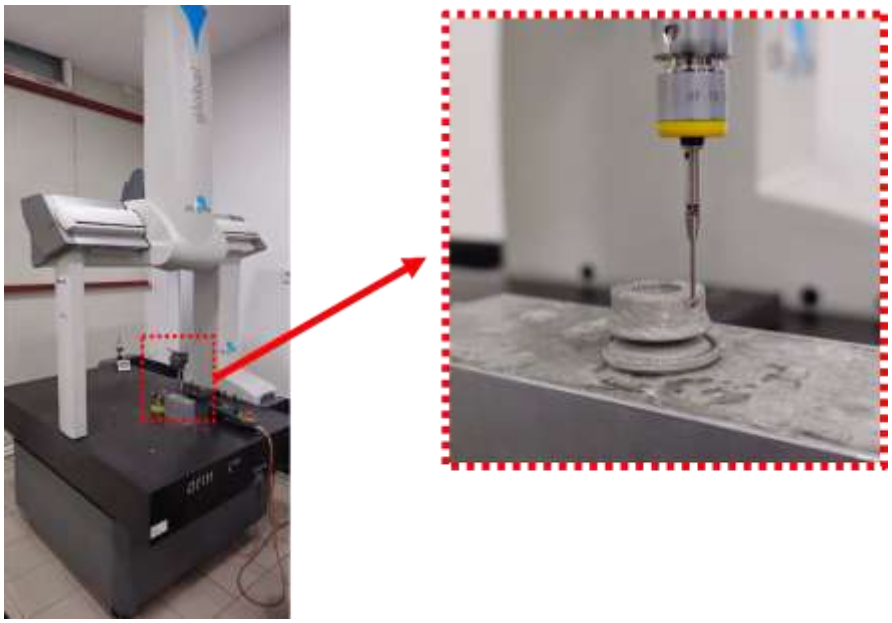


Figure 3. Images of the measurement process using a CMM.

Findings and Discussion

Table 1 presents the relative dimensional deviations between the designed model and the manufactured parts. For practical applications, inner diameters must be produced with negative tolerance, while outer diameters require positive tolerance. Consequently, the fourth and fifth parameter sets are unsuitable for production, as their dimensions fall below the design specifications. In contrast, the first three parameter sets are acceptable for production. In particular, the third parameter set—with a 75 µm BC—produced dimensions very close to the design. This minimizes post-processing effort and reduces overall processing time.

Table 1. Relative dimensional deviation between the designed model and the produced part

Sample	Beam Compensation (BC) (µm)	ID-1 (%)	OD-1 (%)	OD-2 (%)	OD-3 (%)	OD-4 (%)
1	45	-2.34	0.29	0.73	0.45	0.54
2	60	-1.98	0.13	0.43	0.10	0.27
3	75	-0.99	0.33	0.53	0.24	0.28
4	90	0.48	0.01	0.40	0.03	0.34
5	105	0.59	-0.54	-0.01	-0.26	-0.25

*ID: inner diameter, OD: outer diameter

Figure 4 illustrates the influence of BC on part geometry near the borders. When the BC value is low, the laser scan path lies too close to the nominal contour. Due to the outward spread of the melt pool, the effective melting does not fully reach the intended boundary, resulting in undersized dimensions. Conversely, if the BC value is too high, the scan path shifts excessively outward, causing the melt pool to extend beyond the nominal boundary and resulting in oversized dimensions. Thus, dimensional accuracy strongly depends on the alignment between the BC value and the actual melt pool width. In this study, the optimal dimensional accuracy was achieved with a BC value of 75 µm, which closely corresponds to the measured melt pool width. This correlation will be examined in greater detail in future investigations.

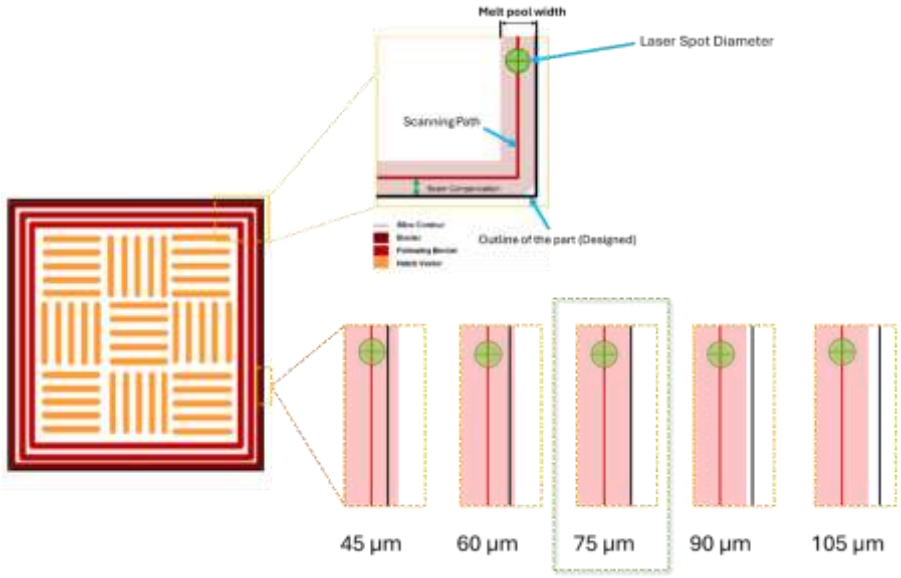


Figure 4. Schematic illustration of the effect of the BC parameter

Conclusion

In this study, the effect of beam compensation (BC) parameters on dimensional accuracy of LPBF-produced part is investigated and following conclusions are obtained:

- BC values significantly influence the dimensional accuracy of LPBF-manufactured components.
- Dimensional accuracy can be optimized solely by adjusting the BC parameter, without requiring any design modifications, provided that the process parameters have already been optimized.S
- Near-net shape parts can be successfully fabricated through LPBF, highlighting the process's potential for precise and efficient production.

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THE ECHO OF ESCAPE FROM REALITY IN DIGITAL CINEMA: INTERPRETING THE SOCIOLOGY OF THE DREAM MOVIE

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ABSTRACT

Communication gains meaning when read on the axis of the reciprocity and intersectionality of the social. Today, the borderlessness and expansion of communication networks have made it necessary to address many phenomena. The variability of the structure and, in fact, the circle of social networks has also begun to find a response in the reality of evaluating the existence of new habituses.

Cinema has also begun to exist and become visible with its own dynamics over time. The subjects, concepts and perspectives addressed have taken cinema far beyond whether it is a pure visual art and have made it necessary to conduct in-depth analyses. In this axis, it has evolved towards evaluation in the context of the discipline of sociology, where many social themes are discussed and examined within cinema. Because cinema needs to include the role of sociology in the process of presenting visuality. It is possible to say that it provides the opportunity to present it in more detail, beyond making analogies at a conceptual level.

This study is based on explaining how the 2016 film “Dream” directed by Derviş Zaim was constructed in the context of digital cinema, how it was conveyed in the context of a mental repertoire, and in fact, discovering the invisible behind the visible. It is important what the photograph of urban life includes with the imagination-friendly metaphors and spatial projections of the introduction of 3-dimensional reflection into cinema. In this context, the class and social context will be presented with a sociological reading will be made around the facts. The main purpose of the study is to establish the umbilical cord between the reflection of the discourses starting from the introduction of the film and sociology. In order to achieve this aim, the basic characters, places, discourses in the film and especially the semantics carried by the title chosen for the film will be examined in the axis of sociological interpretation and critical discourse analysis method.

Keywords: digital cinema, digital angel, imagination-friendly, sociology, dream.

GERÇEKLERDEN KAÇIŞIN DİJİTAL SİNEMADAKİ YANKISI: RÜYA FİLMİNİN SOSYOLOJİSİNİ YORUMLAMAK

ÖZET

İletişim, toplumsalın karşılıklılığı ve kesişimselliği ekseninde okunduğunda anlam kazanmaktadır. Günümüzde iletişim ağlarının sınır tanımazlığı ve yaygınlaştırılması pek çok olgunun da ele alınmasını gerekli hale getirmiştir. Sosyal ilişki ağlarının yapısının ve aslında çemberinin değişkenliği de beraberinde yeni habitusların varlığının değerlendirilmesi gerçekliğinde karşılık bulmaya başlamıştır.

Sinema da zaman içerisinde kendine özgü dinamiklerle var olmaya ve görünür kılınmaya başlamıştır. Ele alınan konular, kavramlar ve perspektifler sinemanın pür bir görsel sanat olup olmaması noktasını çok daha ötesine taşıyarak derinlikli analizlerin yapılmasını da gerekli kılmıştır. Bu eksende sinema içerisinde pek çok toplumsal izleğin tartışıldığı ve irdelendiği sosyoloji disiplini bağlamında değerlendirmeye doğru evrilmiştir. Çünkü sinema, görselliği sunma sürecinde sosyolojinin rolünü dâhil etmeye gereksinim duymaktadır. Kavramsal düzeyde benzetmelerin yapılmasının da ötesinde daha ayrıntılı bir şekilde ortaya koyabilmenin imkânlarını da sağladığını söylemek mümkündür.

Bu çalışma Derviş Zaim tarafından yönetilen 2016 yapımı "Rüya" adlı filmin dijital sinema bağlamında nasıl kurgulandığını, nasıl bir zihinsel repertuar bağlamında aktarıldığını ve aslında görünenin ardındaki görünmeyeni keşfetme noktasında açımlama yapmayı temel almaktadır. 3 boyutlu yansımanın sinemaya girişinin *hayal dostu* metaforlarla ve mekânsal izdüşümleriyle birlikte kentsel yaşamdaki fotoğrafının neyi içerdiği önem taşımaktadır. Bu doğrultuda çalışmada; sınıfsal ve toplumsal bağlam olgular etrafında sosyolojik okuması yapılacaktır. Çalışmanın temel amacı filmin girişinden itibaren yer alan söylemlerin yansıtılış biçimini sosyoloji ile olan göbek bağını kurmaktır. Bu amacı gerçekleştirmek için filmin içerisindeki temel karakterler, mekânlar, söylemler ve de özellikle filme seçilen başlığın taşıdığı anlamsallık ekseninde sosyolojik yorumlama ile eleştirel söylem analizi yöntemi ekseninde irdelenecektir.

Anahtar Kelimeler: dijital Sinema, dijital melek, hayal dostu, sosyoloji, rüya.

Giriş

Sinema, yaşamımızı farklı yönlerden görmeyi sağlayan önemli bir alandır. Toplumun yapısına, kültürüne, hayat tarzına kadar pek çok alanda görünenin ardındaki görünmeyi keşfe yönelik sosyolojik bir yolculuğu temel almaktadır. Bu nedenle de sinemanın pek çok olgu ile birlikte irdelenmesi gerektiğine dair bir okuma yapılması önem taşımaktadır. Sosyoloji disiplinin de etkisi bu noktada ortaya çıkmaktadır. Filmlere dair bilinenlerin farklı yorumları ve analizleri de betimlemeler öte nasıllığına ilişkin geniş bir çerçeveden bakmayı sağlamaktadır.

Rüya filmi kentsel dönüşüm adı altındaki kentsel rantsal alana teslim olunan ve farklı sınıfsallıklardaki mekânsal izdüşümleri üzerinde zihinsel repertuarın değişen ve dönüşen yönleriyle ele alınan yapısıyla sunulmaktadır. Kentsel yenilenmenin yerine piyasanın acımazlığında sınıflar arasındaki eşitsizliğin sosyal adalete yerini bırakmasına ilişkin bir hak temelli okumayı da gerekli kılmaktadır.

Rüya ile gerçek arasındaki zıtlıklarla ya da aynılıklara yansıyan durumsallığın sosyolojisine bakmak çok değerlidir. Bu bağlamda karakterler, mekânlar, kente ilişkin algı, sınıfsallık eksenlerinde filmin yansıtmak istediklerine ilişkin bir değerlendirme yapmak olanaklı hale gelecektir.

Rüya Filminin Toplumsallığının Yöntemi

Bu çalışmanın ayrıksı yönü rüya ile biçimlenen yaşamın istenilen ve arzu edilen ile gerçeklik arasındaki kurulan ya da kurulamayan bağın resmedilişine ilişkindir. Bu resmedilişin sosyolojisini ortaya koyabilmek adına nitel araştırma yöntemin eleştirel söylem analizi ile açımlanışına yer verilecektir. Böylelikle rüya filminin söylemek istedikleri irdelenerek aktarılmaya çalışılacaktır.

Rüya filminin en önemli özelliği geleceğe dair öngörülerde bulunmakta ve bunu da farklı bağlamlarda ve değişen kişilik özellikleriyle aktarmaktadır. Filmin karakterleri ve kullanılan mekânlarda kente, kentleşmeye ve kentlileşmeye dair nüvelerin olduğu ve kapitalist güç ilişkileri temelinde yansıtılması söz konusudur.

Filmin irdelenmesinde nitel araştırma yöntemi (Kuş, 2003) çerçevesinde ele alınmıştır. Bu çalışmada yöntem olarak, araştırma konusuna uygun olmakla birlikte nitel veri analizinin bir türü olan eleştirel söylem analizi kullanılmıştır. Çünkü eleştirel söylem analizi ile sunulanın dışında ve derininde olanın betimleme ve yorumlama yapma alanını da genişletmektedir (Creswell 2013; Van Dijk 2001; 2015; Yıldırım ve Şimşek 2000). Böylelikle yapılacak analizlerde olgusal düzlemde değerlendirmelerin yanı sıra imgelerin ve metaforların resmedilişine özgü açıklamaların da yapılmasını sağlayacaktır. Yaratıcı analizin bir göstergesi olarak eleştirel söylem analizi hem farklılığı bulma hem bunu dile getirme hem de farkındalığı kazandırma gibi pek çok önemli içerimlere de sahiptir.

Rüya: Gerçeklerin Öngörüsüne Dair Bir İpucu



Film, rüya olgusunun içsel yolculuğunun kentsel dönüşüm projelerindeki yaratmış olduğu sınıfsal ve mekânsal eşitsizliğin sosyolojik alt metnini sunmaktadır. Rüya filmi 2016 yapımı Derviş Zaim tarafından yönetilen toplumsal içerikli 3 boyutlu dijital sinemanın görünürlüğüne işaret etmektedir.

Rüya filminin ana karakterleri Sine ve Yâren'dir. Mimar Sine ile Yâren'in karakter analizlerinde kentsel yaşamın sosyal adalet ilkesinden yoksunluğunu, kentsel rantsal alana olan teslimiyetinin gerçekliğini resmetmektedir. Kentsel dönüşüm projeleri genellikle özel sektörün temel aktör olduğu sermaye odaklı projeler olarak görüldükleri için kapitalist ilişkiler çerçevesinde değerlendirilmektedir.

Sine, başarılı bir mimardır ve amcasının inşaat firmasında çalışmaktadır. Sine, cami projesinde yer almaya başlamakta ve film rüyasında gördüğü ve hayal dostu diye metaforlaştırdığı tüm dünyada zamanla meta fetişizmle olan bağlantısı filme konu olmaktadır.

Merkez-periferi, varsıl-yoksul, kadın-erkek dikotomisi bu bağlamda önem taşımaktadır. Bu dikotomilerle birlikte toplumsal gerçekliği bambaşka bir bağlamsallıkta irdeleyen Derviş Zaim kutsal metinlerin insan zihninde uyanışına, farkındalıkla umursamazlık arasındaki med cezirli haline aynı mekânın farklı zamanlarda başka yerlermiş gibi görüntü ile yer verilmesi söz konusudur.



İzleyici 3 d teknolojiyle tanıştıran bir yandan da rüyanın etkisinde kalan Sine ile hayata bakış açısının kentleşme ile olan algılayışına ilişkin nüveler sunmaktadır. Yâren, Sine gibi beyaz yakalı olmayan, sınıfsal olarak kendisini bir bakıma dışlanmış olarak hissetse de sevginin hayal dostu metaforuyla gerçekleşebileceğine inanan bir karakteri resmektedir.

Kentin kapitalist piyasadaki emek akışının yoksulun, periferide yaşayanın aleyhine işleyen eşitsiz yapısını tahakkümcü dil ve davranış pratikleriyle gündelik hayatın sosyolojisindeki nasıl'lığın okuması gözler önüne serilmektedir. Film tamamiyle zıtlıklar üzerine kuruludur. Kentsel dönüşümün kentsel yıkıma yol açtığı, yoksulun varsılın gözünde değersiz görüldüğünü de acımasızlık ilişkisi etrafında aktarılmıştır.

Sine devam eden uykusuzluk rahatsızlığı nedeniyle uyku hastalıkları kliniğine yatar. Yedi uyuyanlar menkıbesini (efsanesini) hatırlatan bir rüya görür. Ertesi sabah klinikte uyandığı zaman fiziksel olarak değişmiş, başka bir kadına dönüşmüştür. Sine fiziki değişime uğramadan önce yapmak isteyip de yapamadığı şeyleri gerçekleştirme özgürlüğünü yaşamaya başlamak istemektedir.

Yedi Uyurlar Efsanesi ile başlayan bir rüya ile Sine karakteri farklı kimliklere bürünmüştür. Yâren'in mahallesi için tasarlanan yeni tarz cami inşaatı başlamıştır. Ancak büyük çaplı bir yer kayması nedeniyle inşaat yarım kalmıştır. Bu cami bilinen geleneksel mimariden çok farklı bir tasarımla inşa edilmiştir. Sine yaratıcılığını özellikle bu cami inşaatında görmek ve göstermek aslında bir yandan da bunu bağlı olduğu ve piyasa odaklı işler yapan ve amcasının patron olduğu mühendislik mimarlık şirketine kanıtlamak istemiştir.

Gelenekselin dışında yapılanın ve kabul edilebilirliğinin öncelikli olmadığı toplumlarda ise yaratıcılığa dair gerek düşünceler ve gerekse bu fikirlerin akabinde oluşturulan üretimler pek hoş karşılanmaz ya da beklentilerin dışında olduğu için direngenlik gösterilir. Direngenliğin bir göstergesi de bu cami inşaatında gerçekleşmiştir. Bir ibadet mekânı bu filmle birlikte gelenekselden kopamayan ve yeniliğe karşı direnç gösteren ile de bir başka dikotomi yaratmıştır.

Dikotomideki tampon kurum ise Yâren karakteridir. Dengeyi sağlayıcı olan Yâren karakteri burada gelişmiş ile az gelişmişliğin arasındaki arafı da betimlemektedir. Yeniliğe açık olmakla birlikte mensubu olduğu sınıftan da kopamayan Yâren karakteri, Sine karakterine olan duygusal anlamdaki hislerini bir anlama bu şekilde ortaya koymaya çalışmaktadır. Ancak yine arada kalmışlığın bir simgesi haline dönüşmektedir. Haliyle insanlar arası kurulan sosyal ilişki ağlarıyla birlikte mekân haline gelen yerlerin konumlanışına ve algılanışına ilişkin farklı gözlerle bakılmasını sağlayan film kareleri sunulmuştur.



Yer kayması dernek üyelerinin bazılarının konutlarının çökmesine de yol açar. Yaren ve arkadaşları mimarlık–müteahhitlik şirketine karşı duruşlarını sertçe olarak ortaya koyduklarında da haklarını aradıklarında da sınıfsal eşitsizliği en derin şekilde yaşamış olurlar.

Cami inşaatında Sine'nin yaratıcılık adı altında bambaşka bir cami inşa etme çabası, dere yatağında inşa edilen konutların insan sağlığına ve canına tehdit oluşturması gerçekleri kapitalist ilişkilerin olağan seyrinde eşitsizlikleri de görünür kılmaktadır. Haliyle karakterlerin yapısının değişime uğramasına, mekânın farklı sosyal statü ve rollere göre değişmesine, davranış örüntülerinin aynı kente ait algılayışın olmayışına dair önemli farkındalıklar sunmaktadır.

Sonuç

İletişimin toplumsal bağlamı kesişimsellikle ilintilidir. İletişimin günümüzde sınır tanımazlığı ilişkiselliğin boyutunu da tanımlamakta yeni olgularla açıklamaya doğru evrilmiştir. Sosyal ilişki ağları da sosyolojik anlamda habitusların gerçekliğini farklılaştırmıştır.

Değişerek durağan olmak gibi bir anlatımla sosyal ilişki ağlarının kentsel hayat yansıyışında yaratıcılıkla üretkenlikten yoksun olmak arasında gidip gelen bir sosyolojik okumaya gebe kalmaktadır. Kentsel hayatın içerisinde merkezde olmak ile öteki olmanın damgalanma halini sınıfsal düzeyde verilmesinin önemi yadsınamaz. Ayrıca mekânsal ayrışmanın heterojenliğinin yerine kendinden olan ve olmayan arasında yaratılan fırsat eşitsizliğine dair bir sosyal kent adaleti ve kent hakkı okumasının (Işık ve Pınarcıoğlu, 2001; Erman, 2010; Kurtuluş, 2010) yapılmasını gerekli kılmaktadır. Filmde de rüya metaforu ekseninde sunulması söz konusudur. Kentin nasıl ele alındığı da burada anlam kazanmaktadır.

Kentler bu anlamda sadece üzerinde nefes alınan mekânlar olmaktan öte kamusal alanların aktif olarak yaşandığı farklı disiplinlerle birlikte algılanması gereken olgudur. Ekonomik, kültürel, politik ve toplumsal bağlamlı olarak kentlerde insanlar yaşamlarını sürdürürken çeşitli faaliyetlerde bulunurlar. Öncelikli olan ise konutların yaşama ne kadar dokunduğu ve nasıl bir

içerimle kurgulanarak inşa edildiğidir. İnsani yaşamdan uzak kırılganlığı arttıran ve sınıfsal olarak farklılıklar ve eşitsizlikler yaratan yapılar ise kentleşmeye ve kentlileşmenin düzeyine ilişkin önemli ipuçları vermektedir.

Film bu anlamda toplumsal gerçekliğin rüyalarla olan bağlantısındaki psikolojik ve sosyolojik yorumunu farklı gözlerden irdelemeye dair geniş bir yelpaze sunmaktadır. Bu yelpazenin boyutu da renkleri de var olanın dışındakine ve gizil olanı aramaya ve bulmaya itmektedir. İşte tam da bu noktada Rüya filmi imgelerin ve simgelerin cami gibi bir ibadet mekânının zaman içerisinde kişiler arasındaki ayrıksılığın ve konutta yaşamanın farklı sınıfsallıklardaki yaşamsallığa yol açışlarının farklı sosyolojik güzergâhlarının vaadini sunmaktadır.

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IMPLEMENTATION OF THE CARBURIZING HEAT TREATMENT PROCESS ON SINT D11 AND SINT D32 MATERIALS A COMPARATIVE ANALYSIS OF THE RESULTS

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ABSTRACT

In this study, the mechanical properties resulting from the carburizing heat treatment applied to SINT D11 and SINT D32 iron-based materials produced by the powder metallurgy method were comparatively analyzed. These materials, manufactured by Höganäs, were first characterized, then subjected to sintering at 1120 °C, followed by carburizing starting at 925 °C.

As part of the mechanical testing, tensile strength, hardness measurements (Brinell, Vickers, Rockwell), and microstructure analyses were conducted. According to the results, although SINT D32 exhibited a coarser pore structure and lower porosity compared to SINT D11, it achieved higher hardness values after carburizing and successfully met the target minimum of 55 HRC. Microstructural analyses revealed carbide formation and phase transformations on the surface of both materials after the carburizing process.

The study concluded that SINT D32 is more advantageous in terms of longevity and performance in applications such as filtration and wear resistance.

Keywords: SINT D11, SINT D32, sintering, carburizing, powder metallurgy

1. Introduction

With today's advancing industry, the ability to produce high-quality and high-performance parts in a single operation without the need for machining has gained importance. The mechanical, physical, and chemical properties of a part play a crucial role in ensuring feasible and repeatable production continuity under operating conditions**.** Powder metallurgy (PM), a good alternative to conventional machining, serves specific industrial applications in this regard (Roberts, 1984).

Powder metallurgy (PM) is a modern manufacturing method that forms parts by bonding very fine particles together. This process enables mass production of small, complex-shaped components that are difficult to manufacture using other conventional methods, through metal powder technologies (Benjamin, 1974).[1]

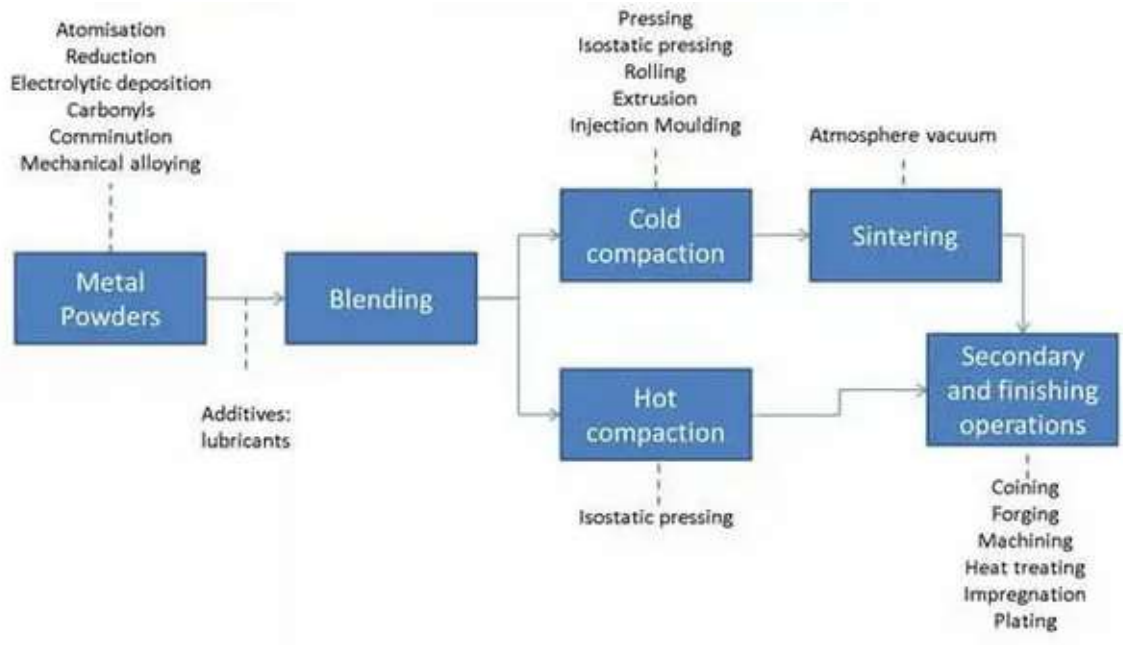


Figure 1. Flow chart of metallic powder processing [2]

2. Materials and Experimental Methods

2.1 Characterization of Powders

In powder metallurgy, powder characterization is the process of determining the physical, chemical, and morphological properties of the metal powders used. These characteristics directly affect the mechanical properties, density, porosity, sintering behavior, and overall performance of the final product.

The characteristics of powders directly influence pressing behavior, shrinkage during sintering, final porosity, mechanical properties, and even surface quality. Especially for high-performance parts (e.g., filters, automotive components, medical implants), powder characterization becomes highly significant [3].

In this study, iron-based powders SINT D11 and SINT D32 produced by the atomization method from Höganäs were used. The chemical and mechanical composition of SINT D11 and SINT D32 powders used in the study is given in Table 1.

Table 1. Composition of SINT D11 and SINT D32 powders

Material	Density Value (g\cm^3)	Chemical and Mechanical Composition											
		Contents (%)								Tensile Strenght MPa	Yield Strenght MPa	Hardness	% Elongation
		C	Cu	Ni	Mo	Sn	P	Fe	Other				
D32	6,8-7,2	0,3-0,9	<3,0	<5,0	0,6-2	-	-	Kalan	<2	520	480	180	1
D11	6,8-7,2	0,4-1,5	1-5	-	-	-	-	Kalan	<2	460	370	130	2

The comparative characterization table of SINT D11 and SINT D32 materials is presented below in Table 2.

Table 2. Material Characterization Table

Property	**SINT D11**	**SINT D32**
Pore Size	~10–12 µm	~25–30 µm
Pore Structure	Fine, dense, small pored	More open, larger pored
Porosity	%30-35	%35-45
Mechanical Strenght	Higher	Lower, but sufficient
Particle Size	~25–40 µm	~60–100 µm
Production Method	Compaction and sintering of fine powders	Compaction and sintering of coarser powders
Filtration Precision	Higher	Lower

2.2 Sintering of Powders

In order to achieve high bond strength between parts joined by sintering, the mechanical interference fit between the components must be properly determined. By narrowing this fit range, an increase in bond strength can be achieved. However, in powder metal green parts assembled with tight mechanical interference, pre-sintering must be applied to prevent the formation of cracks or breakage. In sintering-based joining processes, iron-based powder metal parts are commonly used together with low-alloy carbon steels [4–6].

Since the materials we used SINT D11 and SINT D32 are iron-based, the sintering temperature was set at 1120 °C. Preheating was applied in the range of 550–600 °C. The sintering process was carried out in an endogas protective atmosphere for a duration of 45 minutes. In addition to the sintering operation, a secondary heat treatment process carburizing was also performed.

The parameters of the carburizing process are given in Table 3.

Table 3. Carburizing Process Parameters

HEAT TREATMENT PARAMETERS			
CARBURIZING	**DIFFUSION**	**HARDENING**	**TEMPERING**
925°C %1 C 180 Minutes	850°C %0,70 C 90 Minutes	60° C Oil Quenching 30 Minutes	150°C 120 Minutes

2.3 Mechanical Characterization

The mechanical characterization of materials is critically important for assessing product performance, durability, and operational safety.

2.3.1 Tensile Strength

Due to the brittle nature of porous structures, this test is less frequently preferred; however, it can still be applied for characterization purposes. Tensile testing was conducted in accordance with the ASTM B925 standard. The tensile test results for SINT D11 and SINT D32 are shown below (Tables 4–5).

SINT D11

Table 4. Tensile Test Results of SINT D11 Material

Test Specimen No	***Cross Section Area mm²***	***Lo mm***	***L1 mm***	***Rp%0,1 MPa***	***Rm MPa***	***ELONG %***
1	37.44	30	30.2	362.1	448.7	1.1
2	37.50	30	30.2	358.3	457.9	1.3
3	37.26	30	30.3	364.6	451.9	1.2

SINT D32

Table 5. Tensile Test Results of SINT D32 Material

Test Specimen No	*Cross Section Area* mm^2	*Lo mm*	*L1 mm*	*Rp%0,1 MPa*	*Rm MPa*	*ELONG %*
1	37.44	30	30.2	461.1	488.3	0.6
2	37.50	30	30.2	455.1	497.6	0.6
3	37.26	30	30.3	459.0	481.9	0.8

2.3.1 Brinell Hardness Values (HB)

Hardness is a critical mechanical property in powder metallurgy in terms of both structural integrity and service life. It is particularly related to wear resistance in moving parts or contact surfaces. Hardness is also considered an indicator of the quality of heat treatment and sintering. The hardness values of parts produced with SINT D11 and SINT D32 after the sintering process are presented in Table 6 below.

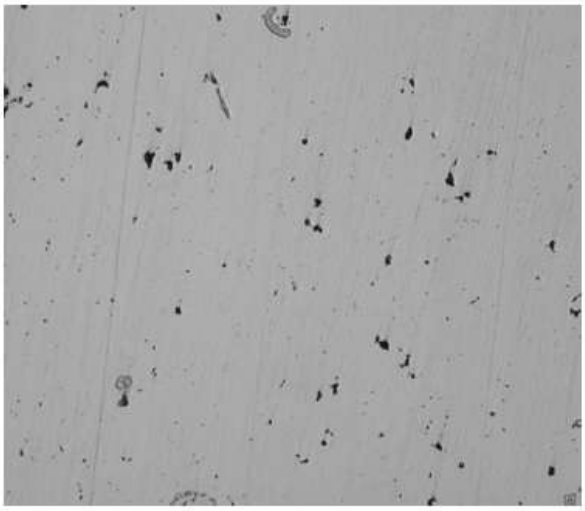
Table 6. Sintered Hardness Results of SINT D11 and SINT D32

HARDNESS VALUES		
PRODUCT	**AFTER SINTERING PROCESS**	**TARGET HARDNESS VALUE**
03L GEAR ***SINT D11***	167 HB	180 HB
03L GEAR ***SINT D11***	170 HB	180 HB
03L GEAR ***SINT D11***	167 HB	180 HB
03L GEAR ***SINT D11***	167 HB	180 HB
03L GEAR ***SINT D11***	170 HB	180 HB
03L GEAR ***SINT D32***	187 HB	180 HB
03L GEAR ***SINT D32***	187 HB	180 HB
03L GEAR ***SINT D32***	191 HB	180 HB
03L GEAR ***SINT D32***	187 HB	180 HB
03L GEAR ***SINT D32***	191 HB	180 HB

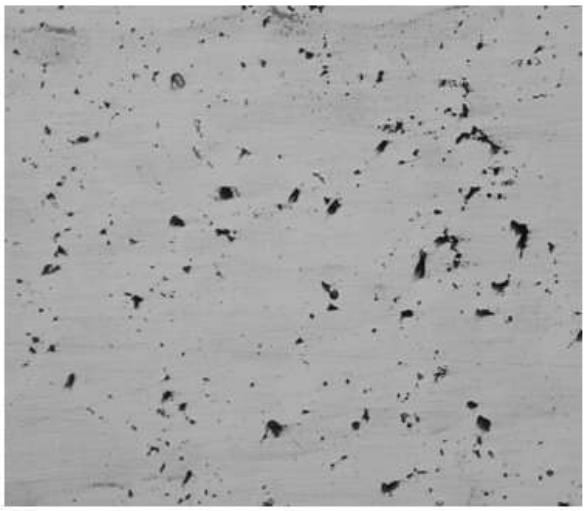
The Brinell hardness testing method was applied to measure the hardness of the products after sintering. Measurements were taken from the surface of the specimens. A ball with a diameter of Ø2.5 mm and an applied force of 187.5 kgf was used.

3. Results and Discussion

Microstructural analysis was performed following the sintering process and subsequently after the combined sintering and carburizing treatment.

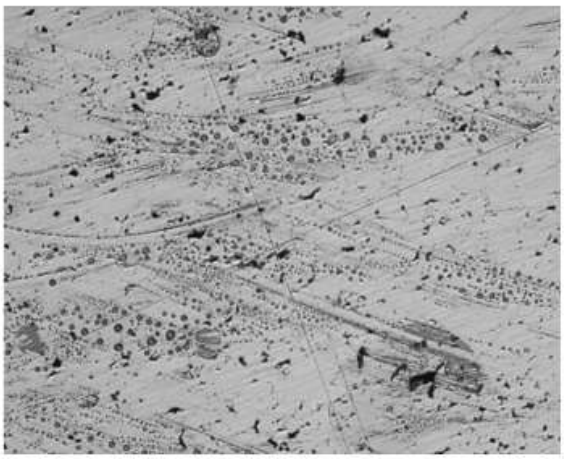


a) Microstructure of Sintered SINT D11

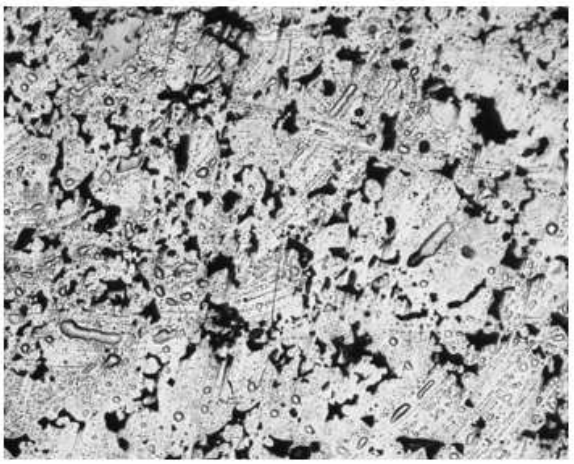


b) Microstructure of Sintered SINT D11

When examining the microstructure shown in Figure a, homogeneously distributed pores can be observed. The structure in the image is typical of a post-sintering microstructure. The presence of pores indicates that the sintering densification process has been completed. The mechanical properties are at a moderate level. In Figure b, the dark areas observed in the image appear to be pores and possibly carbide particles. The matrix phase is light-colored and uniformly distributed, indicating a ferritic structure.



c) Sintered and Carburized SINT D11



d) Sintered and Carburized SINT D32

When examining the microstructure presented in Figure c, it is evident that numerous and densely distributed carbide particles have formed as a result of the carburizing process. A more intense structural change is observed in the subsurface regions, indicating that the carburizing process has diffused inward from the surface. Through carburizing, the surface has been enriched with carbon, forming a harder and more wear-resistant layer.

In the microstructure shown in Figure d, martensitic phase, carbide phases, and precipitates within the pores can be observed. Additionally, linear structures and local patterns are visible, indicating the transformation structure resulting from heat treatment. This structure shows a significant improvement in terms of hardness and wear resistance.

As seen in Table 6, the gear produced with SINT D32 achieved better hardness compared to SINT D11 and reached the target hardness value after carburizing. Considering the wear resistance and long service life in the gear's working environment, it can be concluded that the gear produced with SINT D32 is a more suitable choice.

3.2 Hardness Values of Sintered and Carburized Products

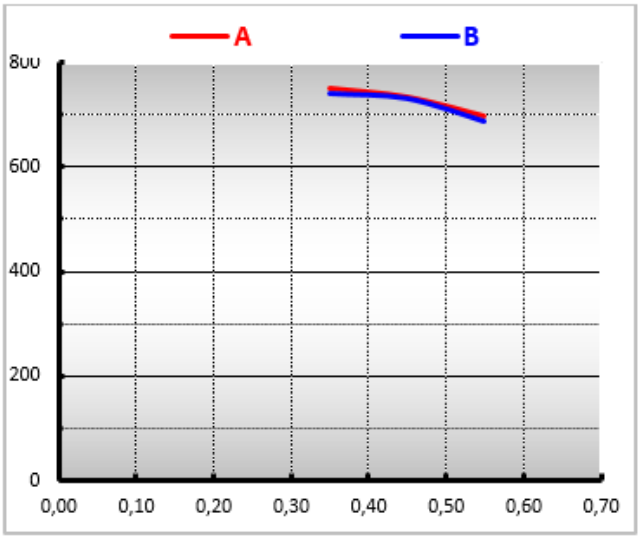
For hardness measurement after carburizing, the Vickers and Rockwell hardness testing methods were applied. Measurements were taken both from the surface and from a depth range of 0.35–0.55 mm of the carburized parts.

Table 7. Carburizing Hardness Results of SINT D11 and SINT D32

PRODUCT	AFTER SINTERING PROCESS	AFTER CARBURIZING PROCESS	TARGET HARDNESS VALUE
03L GEAR ***SINT D11***	167 HB	45,7 HRC	Min. 55 HRC
03L GEAR ***SINT D11***	170 HB	46,4 HRC	Min. 55 HRC
03L GEAR ***SINT D11***	167 HB	48,6 HRC	Min. 55 HRC
03L GEAR ***SINT D11***	167 HB	46,8 HRC	Min. 55 HRC
03L GEAR ***SINT D11***	170 HB	48,2 HRC	Min. 55 HRC
03L GEAR ***SINT D32***	187 HB	57,1 HRC	Min. 55 HRC
03L GEAR ***SINT D32***	187 HB	57,3 HRC	Min. 55 HRC
03L GEAR ***SINT D32***	191 HB	56,4 HRC	Min. 55 HRC
03L GEAR ***SINT D32***	187 HB	55,9 HRC	Min. 55 HRC
03L GEAR ***SINT D32***	191 HB	56,8 HRC	Min. 55 HRC

Table 8. Vickers Hardness Measurement Table and Graph After Carburizing Process

Depth mm	Hardness HV1	
	A	B
0,35	749	740
0,45	733	731
0,55	698	689



In Table 7, we can see the hardness results both before and after carburizing, while Table 8 presents the hardness graph and table of the products measured after the carburizing process. According to the gear's technical drawing specifications, the required minimum hardness value after carburizing is 55 HRC. Gears produced from SINT D11 and SINT D32 materials underwent the carburizing process simultaneously under the same process conditions. It is observed that the gears made with SINT D11 material gained hardness but did not reach the target hardness value. On the other hand, the gears produced with SINT D32 material achieved the desired hardness value.

4. Conclusion

The hardness and structural integrity of parts produced using SINT D32 were found to be superior to those of SINT D11. This indicates that SINT D32 is a more suitable material for applications requiring high wear resistance and durability.

5. Thanks and Information Note

I would like to express my profound gratitude to my advisor, Prof. Dr. Ahmet AVCI, for his invaluable guidance, expertise, and support throughout every stage of this study. I am also deeply grateful to ESTAŞ company for their generous support, the opportunities they offered, and their contributions during both the research and implementation phases.

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MATERIAL-AWARE LINE-OF-SIGHT DETECTION IN INDOOR ENVIRONMENST USING RAY TRACING AND RECEIVED SIGNAL STRENGTH

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ABSTRACT

This study explores the detection of Line-of-Sight (LOS) propagation conditions in an indoor office environment using received signal strength (RSS) as the primary observable. A detailed simulation framework was implemented in MATLAB using a ray tracing model to emulate RF signal propagation from a mobile device positioned at 33,046 unique locations within a confined office space to a fixed receiver. The received signal was modelled for each position as the superposition of all propagation paths, and the total received power was computed accordingly. Measurement instances were geometrically labelled as LoS or Non-LoS based on direct visibility. A statistical hypothesis test was applied to distinguish these two categories based on RSS values alone. The simulation was repeated across homogeneous scenarios to account for material-dependent propagation effects. All surfaces (walls, floors, ceilings) were composed of a single material—plasterboard, concrete, wood, and a perfect electric reflector. The results reveal that each material type yields a distinct received power threshold that optimally separates LoS from non-LoS conditions. These thresholds can be used to adapt LoS detection mechanisms accordingly. Furthermore, the results indicate that the environment's material composition significantly influences LoS detection's reliability. Lighter materials such as plasterboard and wood allow for a clearer separation between LoS and Non-LoS cases in terms of received power, whereas denser materials like concrete produce greater overlap, making classification more challenging. This work contributes to developing material-aware indoor positioning systems by providing a simple yet effective approach for LoS classification, which is crucial for enhancing the reliability of RF-based positioning in structurally diverse indoor environments.

Keywords: Indoor, Line-of-Sight Detection, Received Signal Strength, Surface Material

Introduction

Performance of wireless communication systems heavily rely on the propagation characteristics of radio frequency (RF) signals, particularly in indoor environments where structural complexity can significantly affect signal behavior. A critical concept in understanding and optimizing these systems is Line of Sight (LoS), which refers to an unobstructed, direct visual or electromagnetic path between a transmitter and a receiver. In simple terms, if a signal can travel between two points without encountering any physical obstruction, a line-of-sight condition is said to exist. This concept is not only fundamental in human vision but also one of the most important aspects of wireless communication applications.

LoS is essential for numerous technical tasks such as distance measurement, angle estimation, radar and imaging systems, and high-precision indoor positioning. The presence or absence of LoS directly impacts the received signal strength (RSS) and the quality of the communication link. A clear LoS typically ensures stronger signal reception, reduced interference due to minimized reflections and scattering, and enables higher data transmission rates over longer distances. Conversely, Non-Line of Sight (NLoS) conditions often introduce multipath propagation, signal fading, and significant degradation in communication quality.

The literature provides a robust foundation for understanding LoS-related phenomena in wireless systems. For example, Zhou et al. (2015) and Li et al. (2017) emphasize the significance of distinguishing between LoS and NLoS for accurate indoor positioning using Wi-Fi signals [5][6]. Lv et al. (2022) proposed an artificial neural network (ALNN)-based approach to LoS/NLoS classification in millimeter-wave channels, demonstrating the effectiveness of machine learning in high-frequency environments [4]. Ji et al. (2018) introduced a map-free indoor localization method using ultra-wideband (UWB) arrays, showing that accurate LoS detection significantly enhances positioning performance even in mapless conditions [13].

Cao et al. (2018) conducted a spectral efficiency analysis in massive MIMO systems over Rician channels and highlighted how LoS components play a crucial role in maintaining high throughput and minimizing inter-user interference [3]. Similarly, Turan et al. (2024) analyzed RF signal phase behavior for angle estimation, showing that LoS conditions enable more precise mesh-based elevation angle estimations in linear antenna arrays [1]. Jeong et al. (2017) explored deployment height impacts in low power multihop networks, suggesting that maintaining LoS at optimal heights significantly reduces energy use and hop count [2].

In the domain of motion planning, Zhang et al. (2019) presented a path optimization framework for mobile agents, where reliable LoS detection helps reduce uncertainty in tree-based exploration strategies [7]. Kim (2010) demonstrated that LoS information improves self-organization in swarm robotic systems, particularly when swarm behavior depends on inter-agent visibility [8].

Beyond localization and robotics, Safaie et al. (2016) leveraged LoS properties for improved target localization in harsh environments using direction-of-arrival (DoA) information, underlining its importance in safety-critical applications [9]. Aubry et al. (2024) examined power-aperture allocation in multifunction radar systems, noting that LoS-based optimization strategies enhance both communication and detection capabilities [10]. Similarly, Wang (2021) studied active/passive beamforming in intelligent reflecting surface-assisted radar systems, where LoS knowledge guides efficient beam allocation [11].

Finally, Yin et al. (2013) provided a theoretical basis using Cramér-Rao lower bound analysis for LoS/NLoS geolocation accuracy, revealing that the presence of LoS paths fundamentally

limits the achievable localization error [12]. Collectively, these works underscore that LoS detection is not only a technical requirement but also a foundational enabler across diverse RF-based applications, ranging from communication infrastructure to robotic autonomy and geospatial sensing.

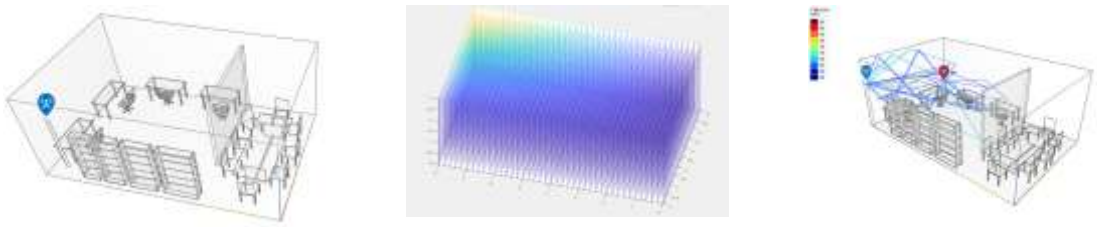
In practical scenarios, LoS detection is not a trivial task due to the influence of environmental materials on signal propagation. Surfaces such as plasterboard, wood, concrete, and metallic reflectors exhibit varying absorption and reflection properties, which affect RSS readings and thus LoS/NLoS classification. This necessitates material-aware approaches, which consider the electromagnetic behavior of the environment in modeling and detection processes.

Understanding and accurately detecting LoS conditions is important in the design of indoor localization systems, wireless sensor networks, 5G/6G communication infrastructures, and Internet of Things (IoT) applications. By incorporating knowledge of the environment's material composition and applying signal strength-based inference techniques, more robust and adaptive positioning algorithms can be developed, paving the way for reliable communication even in complex indoor settings.

In this study, a detailed simulation framework was developed to investigate Line-of-Sight (LoS) detection based on Received Signal Strength (RSS) in a controlled indoor environment. The simulation was implemented in MATLAB and modeled a typical office scenario represented in three dimensions. The office space included walls, ceilings, floors and furniture constructed from uniform materials in each simulation run, including plasterboard, wood, concrete, and a perfect electric reflector, to assess material-dependent signal behavior.

Materials and Methods

A single fixed Access Point (AP) was placed within the office environment to serve as the transmitter. To emulate mobile user positions, a total of 33,046 unique locations were uniformly distributed across the office space. At each of these locations, an identical wireless signal at the central frequency at 2.4 GHz was virtually transmitted toward the AP using a ray tracing-based channel model. This model accounted for key electromagnetic phenomena, including specular reflections, path loss, and phase shifts occurring as the signal interacted with various surfaces.



(a) (b) (c)

Figure 1: *(a) Indoor office environment with the access point (AP) placed, (b) is the 33046 different positions of the mobile device, (c) is the sample transmission from one of the mobile device positions to the AP.*

For every mobile device position, the total received signal was calculated as the superposition of all propagation paths, both direct and indirect, reaching the receiver as in Eq. 1.

$$S_R(t) = \sum_{n=1}^{N} S_n(t) \qquad \text{Eq. 1}$$

S_R is the total signal received, S_n is the signal that is transmitted from n^{th} trace with the transmission effects (pathloss attenuation, phase shift, propagation delay) applied. Received signal power calculated from the received signal samples as in Eq. 2.

$$P_R = \frac{1}{T}\sum_{t=1}^{T}|S_R(t)|^2 \qquad \text{Eq. 2}$$

Each signal transmission instance was geometrically labeled as either LoS or Non-LoS (NLoS) based on the existence of a direct, unobstructed path to the AP. The LoS/NLoS label was then paired with the corresponding received signal strength value.

The obtained received signal power for each 33046 position then be examined with the statistical analysis called Cumulative Distribution Function (CDF), which gives the probability of a random value being smaller than the variable of interest. The definition of CDF is being given in Eq. 3.

$$F_X(x) = P(X \leq x) \qquad \text{Eq. 3}$$

Where $F_X(x)$ is the cumulative distribution function of the random variable X, $P(X \leq x)$ is the probability that X is less than or equal to x.

Through this process, RSS distributions for LoS and NLoS were obtained for the scenarios where the uniform surface materials are plasterboard ($|\Gamma|^2$=0.0697), wood ($|\Gamma|^2$=0.0292), concrete ($|\Gamma|^2$=0.1571), and a perfect electric reflector ($|\Gamma|^2$=1) with reflectivity at 2.4 GHz. These distributions served as the foundation for analyzing how signal strength patterns differ depending on the presence or absence of direct visibility, and how these patterns are influenced by the reflective characteristics of the indoor materials. The results were subsequently used to explore statistical thresholds for classifying LoS conditions, contributing to the development of material-aware LoS detection strategies for indoor environments.

Findings and Discussion

The analysis focused on the statistical behavior of received signal strength (RSS) under LoS and NLoS conditions across various material scenarios. For each material, distributions of RSS were obtained and visualized using the cumulative distribution function (CDF) for LoS and the complementary distribution (1−CDF) for NLoS. This approach provides clear separation between distribution of RSS values for LoS and NLoS scenarios.

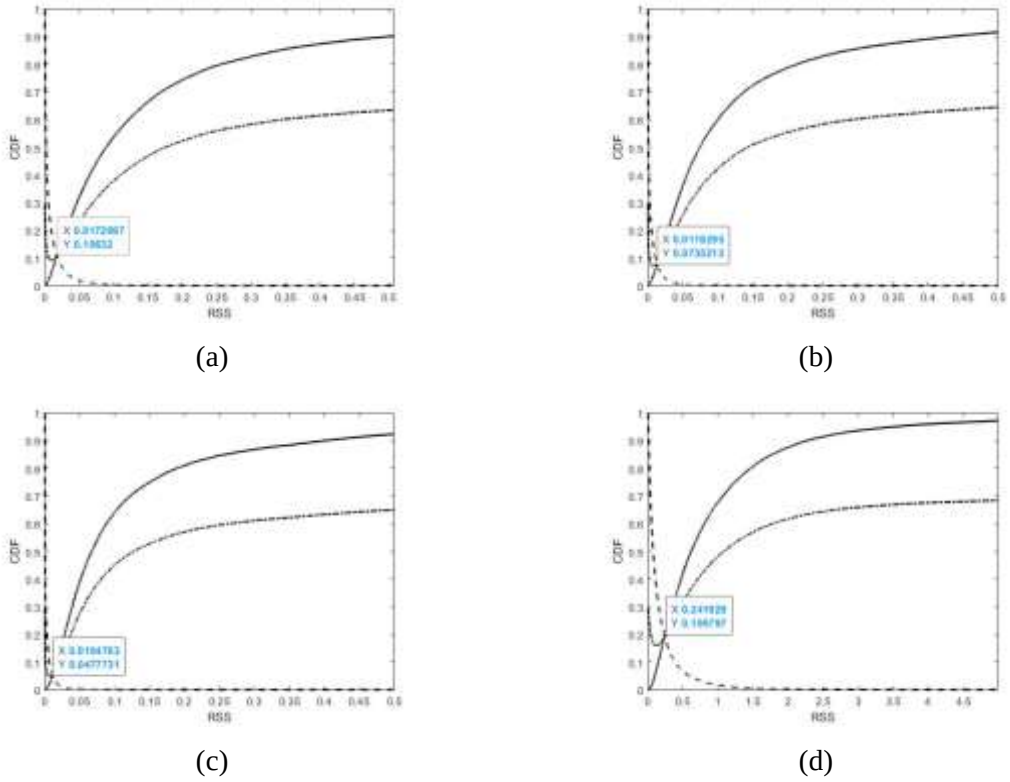


Figure 2: *CDF of RSS distribution for LoS (Straight Line), NLoS (Dashed Line), weighted some of the LoS and NLoS distribution (Dot-Dash Line) and Transmissions* ***(a)*** *Concrete,* ***(b)****Plaster Board,* ***(c)****Wood,* ***(d)****Perfect Reflector.*

The results demonstrated that the LoS and NLoS signal power distributions are material dependent. For lighter materials such as plasterboard and wood, there is a better separation between LoS and NLoS distributions. However, for each material The LoS curves sharply increased at higher RSS levels, while the NLoS curves declined at much lower RSS values. This divergence indicated that RSS thresholding is a simple yet robust approach to LoS detection. In contrast, when concrete was used as the surface material, the separation between LoS and NLoS distributions became less pronounced compared to lighter materials. Although some overlap between the two distributions was observed, the classification based solely on RSS remained effective, maintaining a high level of discriminability. Even in such dense and attenuating environments, the distinction could still be made with a success rate approaching 90%, underlying the robustness of the approach. The perfect electric reflector scenario presented a more challenging case due to uniformly high RSS values in both LoS and NLoS conditions. Nevertheless, the distribution curves were still distinguishable to a significant degree. Despite the reduced gap between signal strength levels, the detection method achieved over 80% accuracy in separating LoS from NLoS. This demonstrates that even in artificially reflective environments, RSS analysis retains substantial classification capability.

Furthermore, the weighted sum of the distributions obtained with the summation of each distribution multiplied with proportion of classified position to the total position. Weighted sum shows that taking a manipulated threshold other than the intersection of the distributions would provide better detection due to the difference in number of LoS positions to NLoS positions.

Overall, the results show that while RSS distribution profiles vary across different surface materials, the RSS thresholding approach maintains reliable LoS detection performance across

all tested scenarios. The ability to achieve high classification accuracy, even in the most challenging conditions, reinforces the applicability of RSS-based methods in diverse indoor environments, especially when calibrated with material-specific considerations.

Conclusion and Recommendations

This study demonstrated that reliable Line-of-Sight (LoS) detection in indoor environments is feasible using only Received Signal Strength (RSS), even under diverse material conditions. A ray tracing-based simulation framework was applied to an office scenario, with 33,046 unique transmission instances categorized into LoS and Non-LoS (NLoS) cases. The empirical analysis of RSS distributions for each case, across different surface materials, revealed a strong correlation between signal strength patterns and visibility conditions.

It was observed that while materials like plasterboard and wood enable clear separability between LoS and NLoS distributions, denser or highly reflective materials such as concrete and perfect electric reflectors introduce a degree of overlap. Nevertheless, the classification performance remained consistently high across all scenarios, with detection accuracies exceeding 90% for most materials and maintaining over 80% even in the most challenging cases.

These results confirm the robustness of the RSS-based LoS detection method and highlight its suitability for deployment in real-world indoor environments with heterogeneous construction materials. The findings further suggest that material-specific calibration can significantly enhance classification reliability, especially in environments prone to strong multipath effects or signal masking.

Future work may explore the integration of phase, time-domain, or directional signal features to improve performance in extreme cases. For example, the obtained phase or arrival angle information may contribute to the RSS threshold decision mechanism. Moreover, the use of data-driven classification techniques, such as machine learning models trained on material-aware signal patterns, may enable more adaptive and generalizable solutions. Nevertheless, threshold-based decision making provides a simple yet effective basis for enhancing indoor wireless communication systems, localization services, and RF environment modeling.

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MIGRATION PHENOMENON IN THE CONTEXT OF THE ECONOMIC IMPACTS OF THE CLIMATE CRISIS

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ABSTRACT

Communities migrated to reach areas where they could survive. Then they became acquainted with agriculture and settled down. Even though the societies that settled down made inventions and discoveries that would revolutionize the age, their utilization of nature to a great extent started to harm nature. With the Industrial Revolution in the 18th century, this damage became more noticeable and led to the climate crisis, a situation that resulted in the deterioration of the ecological balance. Changing climates have degraded the air, water and soil, leading to economic and social problems. All these environmental problems continue to cause migration of people who want to continue their lives in better conditions. This mobility leads to economic problems for both sending and receiving countries. Migration with the butterfly effect and the problems it causes globally pose economic, social and security threats. In the literature, there are studies on migration and economy in the context of the climate crisis. However, the number of studies addressing these three topics of global importance is insufficient for the literature. In this study, it is aimed to examine the two-factor relationship of the migration movement caused by the climate crisis in economic terms. Aynı zamanda iklim krizi, göç ve ekonomi kavramlarının birbiriyle ilişkisine dikkat çekmek ve çözüm yollarına giden arayışa katkı sunmak hedeflenmektedir. Belirlenen araştırma amacı çerçevesinde planlanan biçimde, kavramsal tanımlamalar yapılarak, iklim krizinin göçe sebep olması iklim krizinin ekonomik etkileri ve göç hareketliliğinin sebep olduğu ekonomik sorunlara dair literatür derlemesine yer verilerek, elde edilen bulgular ışığında politika önerileri sunmaya çalışılacaktır. Bu bağlamda çalışmanın, literatüre ve araştırmacılara katkı sunacağı düşünülmektedir.

Keywords: Climate Crisis, Migration, Economy

İKLİM KRİZİNİN EKONOMİK ETKİLERİ BAĞLAMINDA GÖÇ OLGUSU

ÖZET

Topluluklar yaşamalarını devam ettirebilecekleri alanlara uluşmak için göç etmişlerdir. Daha sonra tarımla tanışmış ve yerleşik yaşama geçmişlerdir. Yerleşik yaşama geçen topluluklar, çağ atlatacak nitelikte buluş ve keşifler yapmış olsalar da büyük oranda doğadan faydalanmaları doğaya zarar vermeye başlamıştır. ,18. Yüzyılda Endüstri Devrimi ile bu zarar daha bariz bir biçimde hissedilir hale gelmiş ve iklim krizine yani ekolojik dengenin bozulması ile sonuçlanan bir duruma yol açmıştır. İklimlerin değişmesi havayı, suyu ve toprağı bozmuş, ekonomik ve sosyal sorunlara yol açmıştır. Tüm bu çevresel sorunlar yaşamını daha iyi koşullarda devam ettirmek isteyen insanların göç etmesine sebep olmaya devam etmektedir. Söz konusu hareketlilik ise hem göç veren hem de göç alan ülkeler için ekonomik sorunların oluşmasına yol açmaktadır. Kelebek etkisiyle devam eden göçler ve küresel anlamda sebep olduğu sorunlar ekonomik, sosyal ve güvenlik tehditleri oluşturmaktadır. Literatürde, iklim krizi bağlamında göç ve ekonomiye dair araştırmalar bulunmaktadır. Ancak bu araştırmalar içerisinde küresel öneme sahip bu üç başlığın ele alan çalışmaların sayısı literatür için yetersiz kalmaktadır. Bu çalışmada iklim krizinin neden olduğu göç hareketinin ekonomik açıdan çift etkenli ilişkisinin incelenmesi amaçlanmaktadır. Aynı zamanda iklim krizi, göç ve ekonomi kavramlarının birbiriyle ilişkisine dikkat çekmek ve çözüm yollarına giden arayışa katkı sunmak hedeflenmektedir. Belirlenen araştırma amacı çerçevesinde planlanan biçimde, kavramsal tanımlamalar yapılarak, iklim krizinin göçe sebep olması iklim krizinin ekonomik etkileri ve göç hareketliliğinin sebep olduğu ekonomik sorunlara dair literatür derlemesine yer verilerek, elde edilen bulgular ışığında politika önerileri sunmaya çalışılacaktır. Bu bağlamda çalışmanın, literatüre ve araştırmacılara katkı sunacağı düşünülmektedir.

Anahtar Kelimeler: İklim Krizi, Göç, Ekonomi

GİRİŞ

İklim krizi, dünya genelinde giderek artan doğa olayları, sıcaklık dalgalanmaları, kuraklık, seller ve diğer meteorolojik anormalliklerle kendini gösteren, çok boyutlu ve küresel etkileri olan bir olgudur. Bu kriz, atmosferdeki sera gazı yoğunluğunun artmasıyla birlikte, doğanın dengesinin bozulmasına ve insan yaşamını doğrudan etkileyen çevresel dönüşümlerin hız kazanmasına neden olmuştur (Birpınar, 2022; Parlak vd., 2024). Özellikle Sanayi Devrimi'yle birlikte başlayan fosil yakıt kullanımının yaygınlaşması, üretim ve tüketim desenlerinin değişmesi ve buna paralel olarak hızlanan kentleşme süreci, iklimsel bozulmayı derinleştirmiştir (Başoğlu, 2014). Bu süreçte doğanın sunduğu kaynakların bilinçsiz ve sürdürülemez şekilde kullanımı, iklim sistemlerinde köklü değişimlere yol açmıştır.

İklim değişikliğinin yalnızca çevresel bir sorun olarak ele alınması yetersiz kalmaktadır. Zira bu kriz, ekonomik, sosyal ve demografik yapı üzerinde de ciddi sonuçlar doğurmakta; özellikle kırılgan coğrafyalarda yaşam koşullarını zorlaştırarak insanların yer değiştirmesine neden olmaktadır. Nitekim günümüzde göç olgusu, iklim kriziyle iç içe geçmiş bir şekilde ele alınmaktadır. Özellikle Hindistan, Çin ve Endonezya gibi nüfus yoğunluğu yüksek ülkelerde iklim koşullarındaki bozulmalar, milyonlarca insanın daha yaşanabilir bölgelere yönelmesine sebep olmuştur (Kanbir, 2022).

Göç, insan varlığını koruyabilmek için, beslenebileceği ve güvende olabileceği alanlara doğru hareket etmiştir. Fakat göç artık iklim krizinin etkisiyle günümüzde farklı bir boyuta ulaşmıştır. İlk çağlardan itibaren insanlar, yaşam alanlarını iklimsel ve çevresel koşullara göre belirlemişlerdir. Ancak modern dönemde iklim kaynaklı göç hareketleri, ekonomik ve toplumsal yapılarda derin değişimlere neden olmaktadır. Bu çerçevede, iklim değişikliğinin doğrudan ve dolaylı olarak göçü tetiklediği; göçün ise kaynak ve hedef ülkelerde ekonomik sistemleri dönüştürdüğü bir yapı oluşmaktadır (Parlak vd., 2024). İklim değişikliğinin yarattığı sorunlar, küreselleşen dünyada, su gibi hayati bir kaynağa ulaşma konusunda, geçinebilmek için istihdam edilebilme konusunda, kalabalık nüfus kitlelerinin belirli bölgelerde yoğunlaşmasına sebep olması konusunda sadece göç veren ve hedef ülkeleri değil aynı zamanda bölgesel birlikleri ve hatta dünyanın büyük bir kısmını gittikçe tedirgin eden bir hal almaya başlamıştır. Çünkü görülen ve beklenen göç hareketliliklerinin; başta ekonomik sistemler olmak üzere, sosyal sorunlara, ulusal ve bölgesel sınır güvenliği ihlallerine ve buna bağlı çatışmalara, gıdaya ulaşma savaşlarına gebe birçok boyutlu bir gelecek kendini göstermeye başlamıştır.

Bu açıdan bakıldığında iklim kaynaklı göçlerin ekonomik etkileri oldukça geniştir. Göç eden bireylerin eğitim düzeyleri, mesleki nitelikleri, aile yapıları ve kültürel birikimleri; göçün ekonomik yansımalarında belirleyici unsurlar arasında yer almaktadır (Sırım & Demir, 2020; Aydın & Levent, 2021). Literatürde, özellikle nitelikli iş gücünün göçü- yani beyin göçü- ekonomik kalkınma üzerinde olumlu etkiler doğurduğu sıklıkla vurgulanmaktadır (Gökbayrak, 2008). Bu bağlamda göç, yalnızca bir nüfus hareketi değil; aynı zamanda iş gücünün mekânsal yeniden dağılımı olarak değerlendirilmektedir. Göç alan bölgeler iş gücünü artırarak üretim kapasitelerini genişletebilmekte; göç veren bölgeler ise döviz girişi ve dışsal ekonomik katkılar aracılığıyla ekonomik fayda elde edebilmektedir (Tunalı & Daşdemir, 2023).

Bununla birlikte göçün ekonomik etkileri sadece pozitif değildir. Göçmenlerin entegrasyon süreçleri, işgücü piyasasındaki rekabet koşulları, kayıt dışı istihdam ve ücret baskılanması gibi çeşitli zorlukları da beraberinde getirmektedir. Özellikle yasadışı göçmen istihdamı, iş gücü piyasalarında dengesizlikler yaratmakta ve yerli iş gücü ile göçmen iş gücü arasında haksız rekabet ortamı doğurmaktadır (Konya ve Kabaklarlı, 2023). Bu durum, sosyal ve ekonomik yapının sürdürülebilirliğini tehdit edebilecek boyutlara ulaşabilmektedir.

Sonuç olarak, iklim krizinin ekonomik etkileri bağlamında göç olgusu, küresel ölçekte ele alınması gereken çok katmanlı bir mesele olarak karşımıza çıkmaktadır. Bu çalışmanın amacı, iklim krizinin göç üzerindeki ekonomik etkilerini çok yönlü biçimde inceleyerek hem literatüre katkı sunmak hem de politika yapıcılar için öneriler geliştirmektir. Bu doğrultuda iklim temelli göç hareketlerinin ekonomik yansımaları sistematik biçimde ele alınacak ve mevcut literatür ışığında değerlendirmelerde bulunulacaktır.

İklim Krizi ve Göç Olguları: Kavramsal Çerçeve

İklim, yeryüzünün belirli bir bölgesinde, uzun yıllar boyunca kayıt altına alınmış, atmosferin temel unsurları olan, yağış, nem, basınç gibi hava olaylarının gözlemlenmesi ve istatistiki olarak bulguların ortaya konduğu ortalama değişimleri içeren bir olgudur (İklim Değişikliği Başkanlığı, 2025).

Tüketim döneminin hız kazanmasıyla ekonomi, doğayı sonsuz ve karşılıksız bir hammadde kaynağı olarak görmeye başlamış insan nüfusunun artmasıyla ile yaşam alanları genişlemiş ve bunun sonucunda üretim hızla artmış ve tüketim de beraberinde artmıştır. Enerji sağlayabilmek için kullanılan fosil yakıtlar hızla doğaya zarar vermeye başlamış; atık miktarları ekolojik yapının kendini yenileyebilme kapasitesini zorlar hale gelmiştir (Atvur vd., 2023). Bu durum ise iklim değişikliğine neden olmuştur. İklim değişikliği ise uzun zamanda elde edilen verilerin karşılattırılması neticesinde doğrudan ya da dolaylı olarak küresel atmosferin beşerî faaliyetlerin sonucunda iklimde oluşan değişiklik anlamına geldiğine göre (UNFCC, 2025) ekolojik dengenin bozulmasının başlıca sebebi fosil yakıtların enerji olarak kullanılması ve gıda üretimi ve gelir elde etmek için orman alanlarının tarım alanlarına dönüştürülmesi faaliyetleriyle gerçekleşmiştir. Sonucunda ise, atmosferde karbondioksit seviyesi ve ısıyı tutan diğer gazlar artmış ve küresel ısınma yol açarak iklim seyri değişmiştir. Bu şekilde birbirini tetikleyen olaylar cereyan etmiştir.

İklim değişikliği ayrıca, optimum sıcaklık aralıklarındaki değişimler nedeniyle birçok türün bütünlüğünü ve hayatta kalmasını tehlikeye atmış ve böylece ekosistem yapılarını kademeli olarak değiştirerek biyolojik çeşitlilik kaybını hızlandırmıştır (Abbass vd., 2022). Oluşan bu değişimlerin insan ve doğal yaşam üzerinde görmezden gelinmeyecek olumsuz etkileri iklim krizine neden olmuştur.

İklim değişikliğinin insanlık ve küresel ekosistemler üzerinde derin sonuçları olmaktadır. Ancak bu tür sonuçlar yalnızca çevre, yani doğa üzerinde olmayacaktır. Toprağın altının ve üstünün kirlenmesi ekolojik dengenin bozulması, biyolojik çeşitliğin azalması, ekonomik, sosyal ve politik sorunlara da yol açmaktadır (Atvur vd., 2023). Ekosistem biyolojik çeşitliliğin kaybı, besin kirliliği, türlerin aşırı avlanması, nehirlerden ve suyun azalması, toprak erozyonu ve kimyasal kirlilik gibi faktörler yoluyla önemli ölçüde değiştirilmektedir. Diğer bir deyişle iklim değişikliği çevresel, sosyal, ekonomik ve siyasal alanlara da ciddi zararalar vermektedir. Tüm bu 'diğer' küresel değişikliklerin insan refahı üzerinde büyük etkileri olacaktır ve bu etkilerin çoğu bugün hissedilmektedir (Kosmopoulos, 2024). Dolayısıyla iklim değişikliği, türler, toplulukları, endüstriler ile insanların yaşamlarının her yönünü giderek daha fazla etkilemektedir ve sonuç olarak küresel ekonomi üzerinden ciddi tehditler oluşturmaktadır (Mihailović & Rajičić, 2020). Bu etkiler insanların hayatlarını sürdürdükleri coğrafyadan, geçimlerini sağlayabilecekleri bölgelere göç etmesine neden olmaktadır. Bu hareketliliğin sonucunda hem makro ve mikro olarak hem de ulusal ve uluslararası boyutlarda ekonomik sıkıntılar ortaya çıkmaktadır.

Göç, iklim değişikliğine, ekonomik, politik ve toplumsal faktörlere bağlı olarak son yüzyılda yoğunlaşmış olsa da insanlık tarihinin her zamanında var olagelen bir hareketliliktir.

Dolayısıyla göç, ekonomik, toplumsal, siyasi sebepler dolayısıyla bireylerin veya toplulukların bir ülkeden başka bir ülkeye ya da bir yerleşim yerinden başka bir yerleşim yerine hareket etmesi; taşınma, hicret, muhaceret olarak tanımlanabilir (TDK, 2025). Ancak bu hareket hali çok çeşitli sebeplere dayanmaktadır. Nitekim insanlık ilk zamanlarında hayatta kalmak için göç ederken günümüz açlık, savaş, kıtlık ve iklim koşulları gibi zorunlu nedenlerden kaynaklanan göç nedenlerine günümüzde ek olarak kültürel, siyasi, iktisadi, dini, eğitim, sanayileşme vb. isteğe bağlı sebeplere eklenmiştir (Akıncı vd., 2015). Kısacası iklim krizinin neden olduğu zorlu yaşam koşulları nedeniyle insanlar ekonomik, sağlık vb. diğer sebeplerden göç etmektedirler.

Literatürde İklim, Göç ve Ekonomi İlişkisi

İklim değişikliği ve göç olgusu, son yıllarda sosyal bilimlerin kesişim alanlarında en çok tartışılan konular arasında yer almaktadır. İklim krizinin özellikle ekonomik etkiler bağlamında göçle ilişkisi, disiplinlerarası yaklaşımlarla ele alınmakta; çevre bilimleri, ekonomi, sosyoloji ve siyaset bilimi gibi alanlarda farklı perspektifler ortaya konmaktadır (Black vd., 2011).

Göç ve iklim ilişkisini açıklamaya yönelik ilk teorik yaklaşımlar, çevresel bozulmanın yaşam alanlarını tehdit ettiği durumlarda bireylerin daha güvenli bölgelere göç ettiğini ileri sürmektedir (Myers, 2005). Bu yaklaşım, iklim değişikliğini göçe neden olan temel bir "zorlayıcı faktör" olarak görmektedir. Ancak daha yeni çalışmalar, bu ilişkinin çok daha karmaşık bir yapıya sahip olduğunu, sosyal, ekonomik ve politik değişkenlerin göç kararında önemli rol oynadığını ortaya koymaktadır (Hunter, Luna ve Norton, 2015).

Malthusyen Yaklaşım, gıda artış oranı ile nüfus artış oranının aynı düzeyde olmadığını, gıda artışının artan nüfusa yetişemeyeceğini bu sebeple nüfus artışının önüne geçilmesi gerektiğini vurgulayan katı bir yaklaşım olmasına rağmen nüfus ve gıdaya ulaşımı ilk defa ele alan yaklaşımdır. Malthus'un bu teorisi Endüstri Devriminden hemen sonra ortaya atılmış, insanların geçim olanakları için kırdan kente adeta yığıldığı bir süreç göz önüne alınarak oluşturulmuştur.

Neo-Malthusyen Yaklaşım ise, doğal kaynakların azalması sonucu, tarım ve hayvancılığa dayalı geçim yollarının sürdürülemez bir duruma gelmesi insanları göçe zorladığını ifade etmektedir (Homer-Dixon, 1999). Teorinin çevreye bağlı kıtlıkların göç üzerinde doğrudan etkisine vurgu yaptığı görülmektedir.

Göç Sistemleri Teorisi, ise, göçün yalnızca çevresel zorunluluklarla değil; aynı zamanda sosyal ağlar, kültürel bağlar, ekonomik fırsatlar ve politik faktörlerle şekillendiğini ileri sürmektedir (de Haas, 2010). Bu teoriye göre, bir bireyin göç kararı, yalnızca mevcut iklim koşullarıyla değil; potansiyel göç destinasyonunda var olan iş fırsatları, sosyal entegrasyon imkânları ve geçmiş göç deneyimlerinin etkisiyle de alınmaktadır.

Ayrıca Sürdürülebilir Geçim Yaklaşımı da bu çerçevede önemli bir yere sahiptir. Bu yaklaşım, bireylerin geçimlerini sürdürebilecekleri kaynaklara erişiminin, göç kararlarında belirleyici olduğunu vurgular. İklim değişikliğinin bu kaynaklar üzerindeki etkisi arttıkça, bireyler daha güvenli ve sürdürülebilir bölgelere göç etmektedir (Scoones, 1998).

Bu üç yaklaşım, çalışmanın teorik zeminini oluşturarak iklim değişikliğinin göç üzerindeki ekonomik etkilerini açıklamada kullanılabilir. Özellikle iklim krizine bağlı olarak ortaya çıkan göç dinamiklerinin hem mikro (bireysel) hem de makro (ülkesel/küresel) düzeydeki etkileri bu teorik temeller üzerinden tartışılabilir.

Teorilerde ele alındığı gibi ekonomik boyut, bu tartışmalarda merkezi bir yere sahiptir. Özellikle geçim kaynaklarının yok olması, tarımsal üretimin azalması, su ve enerji kaynaklarına

erişimde yaşanan sıkıntılar gibi faktörler, iklim değişikliğinin ekonomik etkilerini doğrudan göstermektedir. Bu etkiler, özellikle iklim değişikliğine karşı kırılgan ülkelerde göç hareketlerini tetiklemektedir (Warner, 2010). Literatürde, göçün hem ekonomik maliyetleri hem de fırsatları olduğuna işaret edilmektedir. Göçmenlerin işgücü piyasasına entegrasyonu, üretkenliğin artması ve bazı sektörlerde nitelikli işgücü açığının kapatılması gibi olumlu etkiler söz konusu olabileceği gibi; işsizlik, ücretlerin düşmesi ve sosyal gerilimler gibi olumsuz sonuçlar da ortaya çıkabilmektedir (Borjas, 2014).

Cipollina vd. (2021), 96 çalışmanın meta-analizini gerçekleştirerek, iklim değişikliğinin göç üzerindeki etkisinin genel olarak pozitif ve anlamlı olduğunu, ancak bu etkinin coğrafi ve metodolojik farklılıklara göre değiştiğini belirtmişlerdir. Neal vd. (2025), geliştirilmiş ekonomik modellerle, küresel sıcaklık artışının 4°C'ye ulaşması durumunda kişi başına düşen gelirin %40 azalacağını öngörmüşlerdir. Bu çalışma, önceki tahminlerin iklim değişikliğinin ekonomik etkilerini hafife aldığını ortaya koymaktadır. Kahn vd. (2021), 1960–2014 döneminde 174 ülkeyi kapsayan analizlerinde, sıcaklık ve yağıştaki sapmaların uzun vadeli ekonomik büyümeyi olumsuz etkilediğini, özellikle tarım üretimi ve iş gücü verimliliği üzerinde belirgin etkiler olduğunu bulmuşlardır. IMF (2023): 1990–2020 döneminde 5 yıllık verilerle yapılan analizde, iklim afetlerinin tarımsal üretimi ve istihdamı azalttığı, gelir eşitsizliğini azalttığını ortaya koymuşlardır.

Türkiye özelinde yapılan araştırmalarda ise özellikle Suriyeli mülteciler örneği üzerinden iklim kaynaklı olmasa da kitlesel göçlerin ekonomik etkileri analiz edilmiştir (Delice & Tümen, 2015). Özçağ (2011): 1960–2007 döneminde Türkiye için Johansen eş bütünleşme ve ARDL analizleri kullanarak, kişi başına CO_2 emisyonları ile kişi başına gelir arasında uzun dönemli bir ilişki olduğunu ve ekonomik büyümenin emisyonları artırdığını göstermiştir. Başoğlu (2014): 1980–2011 döneminde panel veri analiziyle, iklim değişikliğinin ekonomik büyüme üzerindeki etkilerini incelemiş ve bu etkinin bölgelere göre farklılık gösterdiğini ortaya koymuştur. Güleç (2023): Türkiye'de iklim değişikliği, afetler ve göç dinamiklerinin bölgesel kalkınma üzerindeki etkilerini ele almış ve iklim değişikliğinin göçü artırarak bölgesel kalkınmayı etkilediğini belirtmiştir. Bu çalışmalar, iklim değişikliğine bağlı göçlerin gelecekte artma potansiyeli taşıdığını ve benzer ekonomik sonuçlara yol açabileceğini göstermektedir.

İklim Krizi ve Göç İlişkisi ve Ekonomik Etkileri

21. yüzyılın, ekonomik, politik, çevresel ve toplumsal en önemli sorunlarından birisi haline gelen iklim değişikliği ulusal ve uluslararası ve küresel boyutta etki alanı yaratmıştır. Yağış seyrinin azalmasıyla kuraklıkların artması, sık sık yaşanan ve şiddeti gittikçe artan hava olayları, okyanusların ısı derecesinin artması asitlenerek biyolojik yapısının bozulması, artan ve önlemesi güçleşen orman yangınları gibi iklim felaketleri, insanların sağlığı ve refah düzeyleri üzerinde ciddi etkilere sahiptir. İklim krizi tehdidi global olarak her geçen gün artarken, yaşam koşulları daha güvencesiz hale gelmektedir. İnsan nüfusunun %1 yaşanabilir coğrafyalarda ancak hayatta kalabilecek kadar zor koşullarda yaşarken, 2070'li yıllara gelindiğinde bu oranın%19'a yükselmesi öngörülmektedir (Gürçam, 2023). Tüm bu olumsuz şartlar ulusal ve bölgesel olarak iklime bağlı göçü artan bir güçle tetiklemeye devam edecektir. (Turrentine, 2019). Dolayısıyla küresel anlamda yaşanması olası büyük göç hareketlerinin çok yönlü bir kargaşaya sebep olma olasılığı insanların hayatlarını olumsuz etkileyebilecektir.

Sanayi Devriminden bu yana, özellikle gelişmiş ülkelerin yoğun şekilde fosil yakıt kullanmaları sera gazı salımının hızını artırmıştır. Az gelişmiş ülkeler ekonomik koşullarının elverişli olmaması, hukuki zeminlerinin yetersiz olması, gelişmemiş teknolojiye sahip olmaları, kurumsal altyapılarının oluşmamış olması sebebiyle iklim değişikliğinin olumsuz getirileri ile baş edebilme ve uyum sağlayabilme açısından başarısız olmuşlardır. Bu sebeple bu ülkelerde

yaşayan insanların yaşam koşulları daha kötü hale gelmiştir. Halihazırdaki riskleri daha da artacağı tahmin edilen iklim değişikliği, güvensizliği ve yaşama olan tehdidi de yükselteceği öngörüsü nedeniyle "tehdit çarpanı" kavramı ile nitelendirilmektedir (UN General Assembly, 2009). Tehdit çarpanından iklim krizi nedeniyle şiddetlenen sel, fırtına, kuraklık, sıcak dalgası gibi olayların ilk mağdurları toplumun ekonomik, sosyal ve politik olarak dezavantajlı gruplarıdır. Kırılgan grupların içinde yoksulların yanı sıra kadınlar, çocuklar, yaşlılar, yerli halklar ve yerel topluluklar yer almaktadır (Atvur & vd., 2023). Bu koşullara maruz kalan gruplar için göç bir tercih değil, hayatta kalmak için bir zorunluluk haline gelmektedir

İklim değişikliği sebebiyle gözlenen kuraklık; doğal kaynaklarda azalmaya, verimsizleşmeye, tarım ve hayvancılık başta olmak üzere birçok ekonomik faaliyetin olumsuz etkilenmesine zemin hazırlamaktadır. Ayrıca deniz seviyesinin yükselmesi, hava olaylarındaki değişiklik, yaşam alanlarındaki değişim; günden güne artan sosyo-ekonomik eşitsizlik, siyasal huzursuzluk ve veya istikrarsızlık göç hareketlerinin başlangıç noktası olarak gösterilmektedir (Uysal Oğuz & Atvur, 2023). İklim değişikliğinin baskıları para politikasının sınırlandırılması, artan enflasyon- gıda-enerji ve sigorta maliyetlerine neden olmaktadır (Afiye, 2024). İklim krizi nedeniyle ekolojik ve ekonomik anlamda yüksek risk altındaki bölgelerden göç kaçınılmaz bir durum olarak gündeme gelmektedir (Uysal Oğuz & Atvur, 2023).

Ekonomik kalkınma ve iklim değişikliği arasındaki etkileşimin küresel boyuttaki etkileri yoğun bir şekilde hissedilmektedir. Ekonomik kayıpların niceliği ile ilgili tedirginlikler ülkeleri bu konuda endişeye sürüklemektedir (Mihailović & Rajičić, 2020). Yaşanan ekolojik dengesizlikler sonucu ortaya çıkan iklim krizi bölgeleri ve ülkeleri ekonomik krizin eşiğine sürüklemektedir. Ortaya çıkan ekonomik dalgalanmalardan ülkeler ve coğrafyalar farklı şekilde etkilenmektedir. Ülkelerin coğrafi konumu (Lecocq & Shazili, 2007) ve gelişmişlik düzeyi bu farklılığın başlıca sebebi olarak gösterilmektedir. Özellikle gelişmekte olan ülkelerde ve az gelişmiş ülkelerde, yüksek sıcaklık seviyesi, ekolojik değişime adaptasyonun zayıf olması, erken uyarı sistemlerinin yeterli olmaması, diğer taraftan söz konusu ülkelerin ekonomik yapı kırılganlıkları iklim krizinin ekonomik etkilerini daha ağır yaşamalarına sebep olmaktadır. Aşırı hava koşullarının sermaye stoğuna ve işgücü arzına zarar vererek ekonomik büyümeyi zayıflatmaktadır (Afiye, 2024). İklim değişikliği sebebiyle oluşan olumsuzluklar, hammadde, işgücü ve istihdamı, enerji kaynaklarını negatif yönde etkileyeceği için üretimin azalmasına ve maliyetlerin artmasına sebep olacaktır.

İklim değişikliğinin son yıllarda artan olumsuz etkileri nedeniyle birçok sektör tehlike altındadır. Hava olaylarının dengesiz değişimleri başta tarımda vb. üretim sektörlerini olumsuz etkilemektedir ve nihayetinde ekonomik büyüme oranları üzerinde önemli bir tehdit unsuru oluşturmaktadır (Hayaloğlu, 2018). Bu bağlamda yapılan araştırmalar iklim değişikliğinin, ekonomik büyümeyi üzerinde negatif yönde bir etkisi olduğunu göstermektedir. Bu durum ülke ekonomilerine küresel anlamda zarar vermektedir. Ekonomik aksamalardan dolayı ülkenin gelişmişlik ve büyüme oranları etkilenmektedir (Er, 2025). Örneğin, kuraklığın artmasıyla beraber tarımdaki üretim miktarındaki azalış veya tüketim miktarındaki artış ekonomik dengelerin büyük ölçüde değişimine sebep olmaktadır (Bilgiç, 2017). Dolayısıyla iklim krizi insanlar, ekosistemler, politik, sosyal ve ekonomik yapılar üzerinde yıkıcı etkiler bırakmaktadır (Atvur vd., 2023). Bu etkiler çevresel ve sosyoekonomik alanlarda ortaya çıkabilmektedir. *Çevresel etkileri*; türlerin neslinin tükenmesi, hava kirliliği, suyun azalması, ormansızlaşma ve nihayetinde çölleşme gibi ciddi sorunlar olarak karşımıza çıkmaktadır. *Sosyoekonomik* olarak ise ekonomik kalkınma ve büyümenin sürdürülebilirliğinin azalması, enerji ihtiyacı, gıda ihtiyacı, yoksulluk ve göç olarak karşımıza çıkmaktadır (Türkeş vd. 2000).

Kırsal alandan kentlere doğru yaşanan göç sebebiyle ekonomik faaliyetlere paralel olarak artan enerji ihtiyacını da gündeme getirmektedir

Gözlemlenen sıcaklık artışları, doğal felaketler, yağışlardaki kontrolsüz dalgalanmalar, iklim değişikliğinin yalnızca ekosistemde bulunan canlıları değil ekonomiyi de etkilemesi sonucunu doğurmaktadır. İstihdam, sağlık, emek kayıpları, sektörel etkileri, ekonomik büyüme, ekonomik kayıplar gibi olumsuz durumların ortaya çıkmasına neden olmaktadır. Ekonomik açıdan dezavantajlı bulunan gelişmekte olan ülkeler iklim değişikliği ile ilgili gereken tedbirleri almakta yetersiz kalmaktadır. Bilinçsiz bir şekilde kıt kaynakların tüketimi, ekosistemde meydana gelen krizler, küresel ekonomik dalgalanmalar, yenilenemez enerji kaynaklarından doğan çevresel zararlar, insanları farklı çözüm arayışlarına yöneltmektedir.

Yaşanan ve yaşanması muhtemel olan ekonomik sorunlar sebebiyle istihdam, refah seviyesinde azalma meydana gelerek, yoksulluk ve sosyoekonomik güvensizlik sebebiyle sosyal istikrar sorunlarının yaşanması kuvvetle muhtemel gözükmektedir.

İklim Krizi, Göç ve Ekonomik Etkilerine Yönelik Bölgesel ve Küresel Politikalar

İklim değişikliğinin tetiklediği göç dalgaları, özellikle tarımsal üretime dayalı ekonomilerde ve altyapı kapasitesi sınırlı bölgelerde hem göç veren hem de göç alan topluluklarda ciddi ekonomik sonuçlar doğurmaktadır (Black vd., 2011). Tarımsal verimliliğin düşmesi, geçim kaynaklarının yok olması, altyapı hasarları ve yaşam koşullarının bozulması bireyleri yer değiştirmeye zorlamakta; bu zorunlu hareketlilik ise hem kaynak hem de hedef bölgelerde ekonomik kırılganlıkları artırmaktadır (IOM, 2019). Dolayısıyla, iklim kaynaklı göçü yalnızca insani bir mesele olarak değil, aynı zamanda ekonomi-politik bir sorun alanı olarak değerlendirmek gerekmektedir.

İnsanoğlu farklı sebeplerle yaşam alanlarındaki tahribat sonucunda, ülke içinde veya dışında göç hareketinde bulunmaktadır. Bu bağlamda insanları göç etmeye zorlayan belli başlı sebepler olarak; doğal afetler, alt yapı sorunları, can ve mal güvenliği, ekonomik sebepler ve kültürel aktörler gösterilebilir. (IPCC, 2022, ss.8-19). Bu sebepler dolayısıyla iklim krizine dayalı göçler hali hazırda dünyada yaşanan insan hareketlerinin fitilini ateşleyerek büyük bir hareketliliğin başlangıç noktasını oluşturmaktadır. İklim krizinin ulusal ve uluslararası etkileri, ülkeler arası eşitsizliğin yanı sıra sosyoekonomik eşitsizliği, cinsiyet eşitsizliğini ve politik istikrarsızlığı artırmaktadır. Ekonomik kayıplar ise yaşam kalitesini kötüleştireceği ve ölümlere yol açarak göçlere neden olabilmektedir (Uygur ve Atvur, 2023).

Günümüzde yaşanan, afetler, savaşlar ve iklim değişiklikleri gibi birtakım olaylar küresel anlamda birçok insanı yerinden ederek, göç hareketliliği önceki iki katına çıkmıştır (Gürçam, 2023). Dolayısıyla iklim krizi çerçevesinde oluşan insan hareketliliğinin halihazırda gözlenen düzensiz göç sorununu gündeme getirecektir. Bu sebeple olası risk ve tehditler insanların, toplumların ve devletlerin, ekosistemlerin güvenliğinin uluslararası dayanışma ve iş birliği kapsamında ele alınmayı zorunluluk haline getirmektedir (Atvur vd., 2023). Ancak her geçen gün kötü hale gelen iklim kayıpları ve daha da şiddetli hava olayları insan hareketliliğinde bir artışa neden olduğundan dolayı göç etmeyi seçen insanlar bunu çok az yasal koruma ile yapmaktadır. Var olan uluslararası hukuk sisteminde ülkeleri, iklim krizi nedeniyle göç eden kişileri desteklemeye zorlayan yasal olarak bağlayıcı anlaşmalar bulunmamaktadır (Berchin, Valduga, Garcia ve Andrade Guerra, 2017). Bu bağlamda iklim krizi nedeniyle göç eden kişiler mültecilere benzese de uluslararası hukuk sisteminde yer alan mülteci statüsünden faydalanamamaktadırlar (Lister, 2014). İklim krizi ile göç arasındaki ilişki, ulusal ve uluslararası düzeyde hâlen yeterince sistematik şekilde ele alınmamış ve çoğu zaman insani krizler bağlamında geçici çözümlerle yönetilmeye çalışılmıştır (Bettini, 2013). Ancak iklim

göçünün kalıcı, artan ve karmaşıklaşan bir olgu olduğu artık bilimsel verilerle de desteklenmektedir. Nitekim Dünya Bankası'nın 2021 yılında yayımladığı rapora göre, 2050 yılına kadar Sahra Altı Afrika, Güney Asya ve Latin Amerika'da 216 milyona yakın insanın iklim koşullarına bağlı olarak iç göçe zorlanabileceği öngörülmektedir (World Bank, 2021). Bu durum, ekonomik kaynakların yeniden dağılımı, kentleşme baskısı, iş gücü piyasalarında dengesizlikler ve sosyal uyum sorunları gibi çok sayıda yeni meydan okumayı da beraberinde getirmektedir. Bu çerçevede ulusal ve uluslararası düzeydeki örgütlerin güvenlik stratejilerinde iklim değişikliğinin yıkıcı etkileri yerini almış ve bu etkilerin sebep olduğu göç hareketlerine yönelik önlem olarak ulusal güvenlik kapsamında ele alınmaya başlamıştır (NATO, 2021; The White House, 2015; HM Government, 2010).

İklim değişikliğine bağlı zorunlu göç, giderek artan ölçüde küresel yönetişim sisteminin sınamalarından biri haline gelmiştir. Bu bağlamda, iklim göçü yalnızca çevresel değil; aynı zamanda sosyoekonomik, siyasi ve hukuki bir mesele olarak bölgesel ve küresel düzeyde çok aktörlü çözümler gerektirmektedir. Ancak hâlihazırdaki bölgesel ve uluslararası mekanizmalar, bu karmaşık sorunu yönetmekte yetersiz kalmakta; özellikle göçün temelinde yatan kırılganlıkları önleyici değil, sonuçlara tepki veren politikalar ön planda tutulmaktadır (Boas vd., 2019; IOM, 2023).

Uluslararası hukuki ve politik çerçeve ye bakıldığında ilk olarak Cenevre Mülteci Sözleşmesi'ne rastlanmaktadır. İklim göçmenlerinin veya "çevresel mültecilerin" mevcut uluslararası hukukta tanımlı bir statüsü bulunmamaktadır. 1951 Cenevre Mülteci Sözleşmesi, yalnızca ırk, din, milliyet, belli bir sosyal gruba mensubiyet ya da siyasi görüş nedeniyle zulüm gören bireyleri mülteci olarak tanımladığından, iklim değişikliği kaynaklı göçmenler bu tanıma girmemektedir (McAdam, 2012). Bu durum, özellikle ada ülkelerinde yaşayan ve deniz seviyesinin yükselmesi gibi geri döndürülemez etkilerle karşı karşıya kalan topluluklar için ciddi bir koruma açığı yaratmaktadır.

Paris İklim Anlaşması (2015), ilk defa uluslararası düzeyde yerinden edilme riskine dolaylı biçimde değinmiş, 8. maddesi ile "kayıp ve zarar" (loss and damage) mekanizması içinde göç konusuna atıf yapmıştır. Ancak bu atıf, herhangi bir bağlayıcı yükümlülük içermemektedir. Bununla birlikte, COP26 ve COP28 gibi son iklim zirvelerinde, iklim göçü meselesi daha görünür hale gelmiş; ancak somut adımlar sınırlı kalmıştır (UNFCCC, 2023). BM Küresel Göç Mutabakatı (Global Compact for Safe, Orderly and Regular Migration, 2018), çevresel göçmenlerin korunması konusunda önemli bir dönüm noktası sayılabilir. Bu mutabakat, göçün "çevresel, iklimsel ve afet kaynaklı nedenleri"ni kabul etmekte ve iklim değişikliğinin göç üzerindeki etkilerine yönelik önleyici ve uyumlayıcı önlemler geliştirilmesini teşvik etmektedir. Ancak yine bağlayıcılığı bulunmamakta, uygulama büyük ölçüde devletlerin isteğine bırakılmaktadır (UN, 2018).

Bazı bölgeler, iklim kaynaklı göç konusunda özgün uygulamalar ve politika örnekleri geliştirmiştir. Örneğin Pasifik Adaları ve Okyanusya' deniz seviyesindeki yükselme nedeniyle toprak kaybı yaşayan Tuvalu, Kiribati ve Marshall Adaları gibi ülkeler, vatandaşlarını diğer ülkelere gönüllü olarak yeniden yerleştirme stratejileri geliştirmektedir. Yeni Zelanda, bu çerçevede 2017 yılında "iklim mültecisi vizesi" üzerinde çalışmaya başlamış, ancak uygulamaya koymamıştır. Kiribati hükümeti, Avustralya'da arazi satın alarak gelecekteki yeniden yerleşim planlarını gündeme taşımıştır (Burson, 2020).

Afrika Kıtası'nda iklim değişikliği ile gıda güvensizliği, kuraklık ve su kıtlığı arasındaki bağ nedeniyle en fazla etkilenen bölgelerden biri olan Afrika'da, IGAD (Doğu Afrika Hükümetler arası Kalkınma Otoritesi), iklim göçü risklerini haritalayan ve erken uyarı sistemleri kuran politikalar geliştirmiştir (IOM, 2021). Ayrıca, Afrika Birliği'nin 2009 tarihli Kampala

Sözleşmesi, yerinden edilme olgusuna çevresel faktörler bağlamında dolaylı atıflarda bulunmaktadır. Bu durum, bölge içindeki hukuki tanımanın bir ön adımı olarak yorumlanmaktadır (AU, 2009).

Avrupa Birliği, Afrika'dan gelen düzensiz göç dalgalarını iklim temelli de olsa güvenlik odaklı ele almakta; göçü önleyici sınır politikaları ön planda tutulmaktadır. "Yeni Göç ve İltica Paktı" (2020), çevresel nedenlerle yerinden edilen bireyleri açık biçimde ele almamaktadır. Ancak AB fonları ile özellikle Sahra Altı Afrika'da dayanıklılık artırıcı projeler desteklenmektedir (Geddes & Sommerville, 2022). Bu çabalar, sorunun kaynağına değil, sonucuna odaklanması nedeniyle eleştiriye açıktır.

IOM (*International Organization for Migration*, Uluslararası Göç Örgütü), UNHCR(*United Nations High Commissioner for Refugees* Birleşmiş Milletler Mülteciler Yüksek Komiserliği), FAO(*ood and Agriculture Organization of the United Nations*, Birleşmiş Milletler Gıda ve Tarım Örgütü), UNDP(*United Nations Development Programme*, Birleşmiş Milletler Kalkınma Programı) ve WFP(*World Food Programme*, Dünya Gıda Programı) gibi çok taraflı kuruluşlar, iklim göçünün etkilerine karşı uyum politikaları, risk azaltımı ve erken müdahale çerçeveleri oluşturmaktadır. Özellikle IOM, 2021-2030 yıllarını kapsayan kurumsal stratejisi içinde iklim kaynaklı hareketliliğe özel yer ayırmış ve çevresel göçün izlenmesi için veri tabanları geliştirmiştir (IOM, 2021). Ancak uygulamalar genellikle proje temelli ve fon bağımlıdır; bu da uzun vadeli sürdürülebilirlik açısından zorluk yaratmaktadır. Yeşil İklim Fonu (GCF) ve Adaptasyon Fonu, düşük gelirli ülkelerin iklim değişikliğine uyum kapasitesini artırmaya yönelik finansman sunmaktadır. Ancak bu fonların iklim göçünü açık hedef olarak alması hâlâ sınırlıdır (UNFCCC, 2023).

Genel olarak, iklim değişikliğine bağlı göçü ele alan bölgesel ve küresel politikalar; hukuki tanım eksikliği, politika uyumsuzluğu, bağlayıcılık zafiyeti, fon dağılımı ve yönetişim sınırlılıkları gibi nedenlerle yetersiz kalmaktadır. Uluslararası toplum, iklim göçünü geçici krizler yerine, kalıcı sosyoekonomik bir gerçeklik olarak kabul etmeli; bu doğrultuda küresel iş birliğine dayalı, insan hakları temelli bağlayıcı politikalar geliştirmelidir (McLeman, 2020; Warner vd., 2022). İklim krizinin etkileri giderek derinleşirken, iklim göçünü uluslararası hukukta tanımlayan ve hak temelli yaklaşımları önceleyen bağlayıcı mekanizmaların oluşturulması artık ertelenemez bir ihtiyaçtır.

SONUÇ

Sanayi devrimi ile birlikte kontrolsüz şekilde artan üretimin sebebi olan tüketim doğanın tüm olanaklarını kullanmaya başlamıştır. Zamanla sürekli tüketim anlayışı doğanın ve insan yaşamının dengesini sarsmıştır. Nihayetinde ise iklim krizi, ekonomik sorunlar ve bunlara bağlı göç hareketleri yaşanmaya başlamıştır.

Günümüz dünyasında günden güne toplumu tehdit eden yeni sorunlara ek olarak, iklim değişikliği de kendine yer bulmuştur. İklim değişikliği sorunu çevresel, siyasal, ekonomik ve sosyal açıdan küresel ölçekte çözüm bekleyen en önemli sorunlardan birisidir. İklim değişikliğiyle küresel ısınmanın sebep olduğu etkiler arasında buzulların erimesi de yer almaktadır. Bu durum okyanus akıntılarında yön değişikliği, fırtınalar, yağışlar veya kuraklık gibi bir takım tabiat olaylarının oluşumunu sağlamayarak, ekosistemleri ve biyolojik çeşitliliği olumsuz etkilemektedir. İklim krizine karşı gereken önlemlerin alınmaması veya duyarsızlığın devam etmesi durumunda, günden güne etkileri çığ gibi büyüyerek özellikle az gelişmiş ülkelerde kendini daha fazla göstermeye devam edecektir. Bu etkiler her geçen gün daha fazla hissedildikçe insanlar ilk olarak ulusal sonrasında uluslararası düzeyde göç hareketlerine yönelmeye devam edecektir.

İklim krizi tarımsal verimliliğin düşmesine, geçim kaynaklarının azalmasına, altyapı sorunları ve yaşam koşullarının kötüleşmesine neden olmaktadır. Bu durum bireyleri göçe etmeye zorlamakta; bu zorunlu hareketlilik ise hem kaynak hem de hedef bölgelerde ekonomik kırılganlıkları artırmaktadır.

Son 10 yılda yaşanan göç hareketliliğinin kontrolsüz artışı göz önüne alındığında bu durum, ekonomik dengesizlikleri, kentleşme sorunlarını, iş gücü piyasalarında dengesizlikler ve sosyal uyum sorunları gibi çok sayıda yeni zorluğu beraberinde getirmektedir.

Bu sorunlarla mücadelede uluslararası boyutta insan haklarını koruyan ve uygulanabilir politikalar geliştirmesi gerekmektedir. Mevcut uluslararası hukuki çerçeve iklime dayalı göç eden kişilerin "mülteci" statüsünde yer almaması, bu kişilerin yasal korumadan mahrum kalmasına yol açmaktadır. Paris İklim Anlaşması ve BM Küresel Göç Mutabakatı gibi girişimler umut verici olsa da uygulama eksiklikleri nedeniyle yetersiz kalmaktadır.

Dolayısıyla, iklim krizinin neden olduğu ekonomik faaliyetler bağlamında göç kavramına etkilerinin incelenmesi ve bu kavramların birbiriyle ilişkisine dikkat çekilmesi, küresel çözümlerin geliştirilmesi açısından büyük önem taşımaktadır. İklim krizine karşı acil ve donanımlı planların yanı sıra, iklim kaynaklı göç eden kişiler için uluslararası koruma anlaşmalarının düzenlenmesi ve insani yardımların artırılması gerekmektedir.

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IMPACTS OF CLIMATE CRISIS AND MIGRATION ON FOOD SECURITY: POLICY AND STRATEGIC APPROACHES FOR SUSTAINABILITY

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ABSTRACT

Since the Industrial Revolution, meeting the need for energy in production from fossil fuels has led to a decrease in underground resources on the one hand, and to an increasing deterioration in the balance of the ecosystem due to wastes on the other. All these negativities have resulted in global warming and climate change. Weather events caused by climate change, drought, decrease in agriculture and food production, and difficult access to food have triggered migration movements of masses. In particular, conditions where environmental vulnerabilities are intense force the people of the region to migrate in order to change their livelihoods. This situation creates food supply and demand, security and demographic problems for both sending and receiving countries. Although war and economic conditions are the most common causes of migration in the literature, the concepts of "climate migrants-climate refugees", which have not yet been defined in international law, have started to take place in migration studies. Because it is stated in international platforms that the migration movements caused by the climate crisis will intensify. Therefore, climate crisis and migration can be considered as two important factors threatening food security. The importance of sustaining access to food and water and increasing resource efficiency has moved to a human dimension as well as being a national and regional problem. This study aims to provide sustainable agriculture, water management, food security policies, social cohesion policies and future perspectives by analyzing the effects of climate change and migration on food security. On the other hand, it is aimed to make a general evaluation in terms of the sustainability of the economies of migration-receiving and migration-giving countries and to make suggestions and to contribute to the literature in this respect.

Keywords: Climate Crisis, Migration, Food Security, Sustainability

İKLİM KRİZİ VE GÖÇÜN GIDA GÜVENLİĞİ ÜZERİNE ETKİLERİ: SÜRDÜRÜLEBİLİRLİK İÇİN POLİTİKA VE STRATEJİK YAKLAŞIMLAR

ÖZET

Endüstri Devrimi'nden itibaren üretimde enerji ihtiyacının fosil yakıtlardan karşılanması bir taraftan yeraltı kaynaklarının azalmasına diğer taraftan atıklar sebebiyle gittikçe artan şekilde ekosistemin dengesinin bozulmasına sebep olmuştur. Bütün bu olumsuzluklar küresel ısınma ve iklim değişikliği ile sonuçlanmıştır. İklim değişikliğinin yol açtığı hava olayları, kuraklık, tarım ve gıda üretiminin azalması, gıdaya ulaşmanın zorlaşması kitlelerin göç hareketlerini tetiklemiştir. Özellikle çevresel kırılganlıkların yoğun yaşandığı şartlar bölge halklarını geçim kaynaklarını değiştirmek amacıyla göç etmeye zorlamaktadır. Bu durum ise hem göç veren hem de göç alan ülkeler için gıda arzı ve talebi, güvenlik ve demografik sorunlar ortaya çıkarmaktadır. Literatürde, savaş ve ekonomik koşullar göç sebepleri arasında en çok yer alan konular olsa da henüz uluslararası hukukta tanımlanmamış olan "iklim göçmenleri-iklim mültecileri" kavramları göç çalışmalarında yer almaya başlamıştır. Çünkü iklim krizinin yaratacağı göç hareketlerinin yoğunlaşacağı uluslararası platformlarda dile getirilmektedir. Dolayısıyla iklim krizi ve göç, gıda güvenliğini tehdit eden iki önemli faktör olarak kabul edilebilir. Gıda ve suya ulaşılabilmenin sürdürülebilmesi, kaynak verimliğinin artırılmasının önemi, ulusal ve bölgesel sorun olmasının yanı sıra insani bir boyuta da taşınmıştır. Bu çalışma, iklim değişikliği ile yaşanan ve yaşanacak olan göçün gıda güvenliğini üzerine etkilerini analiz ederek, sürdürülebilir tarım, su yönetimi, gıda güvenliği politikaları, sosyal uyum politikaları ve gelecek perspektifi sunmayı amaçlamaktadır. Diğer taraftan göçe bağlı arz talep dengesinin pek çok bakımdan değişmesi göç alan ve göç veren ülke ekonomilerinin sürdürülebilirliği açısından genel bir değerlendirmenin yapılarak önerilerde bulunmak ve bu bakımdan literatüre katkı sunmayı amaçlanmaktadır.

Anahtar Kelimeler: İklim Krizi, Göç, Gıda Güvenliği, Sürdürülebilirlik

Giriş

Küresel ölçekte giderek büyüyen bir tehdit halini alan göç olgusu, her zaman savaş ya da güvenlik arayışı sebepleriyle gerçekleşmemektedir. Günümüzde küresel dönüşümlerin temel dinamiklerinden biri olarak kabul edilen iklim krizi, zorunlu göçün temel nedenlerinden biri haline gelmiştir. İklim krizi, zorunlu göçlerin bir sebebi olmakla birlikte, üretimin artarak devam edebilmesi için girdi olarak kullanılan doğal kaynakların dengesinin bozulmasının, üretim süreçlerinde ortaya çıkan ve hızlı tüketim kalıplarının yarattığı çevresel kirliliğin de bir sonucudur. Bu sebeple iklim değişikliğine hava olaylarında meydana gelen değişim olarak görmek, dar bir çerçeveyi işaret etmektedir. Çünkü günümüzde küresel sıcaklıklarda artış olması, kuraklık, sel ve fırtına gibi hava olaylarının sıklığının ve şiddetinin artması boyutundan çıkmış bir iklim krizine dönüşmüştür. Söz konusu doğa olayları artık insanları, geçimlerini sağlayabilmek, hayatta kalabilmek için gıdaya ve suya ulaşabilme, güvenli alanlarda yaşayabilme imkânı bulmak için göçe mecbur bırakmaktadır. Dolayısıyla iklim değişikliğinin nedenleri ve sonuçları üzerinde ciddiyetle durulması zorunluluk haline gelmiştir. Ekolojik dengenin bozulmasıyla iklim krizi ile mücadele eden yerkürenin yaşadığı iklimsel sorunlar sonucunda yaşanan göçler sadece belirli bir ülke ya da bölgeyi değil artık küresel bir sorun olarak bütün dünyayı etkisi altına almaya başlamaktadır. İklim krizi, 1972 Stockholm Konferansı ile uluslararası arenada mücadeleye başlanılan bir konudur.

Dünya genelinde derinleşen iklim krizi, çevresel bir tehdit olmanın ötesine geçerek sosyo-ekonomik yapılar, yerleşim dinamikleri ve temel insan hakları üzerinde çok boyutlu ve derin etkiler yaratmaktadır. Özellikle gıda ve temiz suya ulaşma konusu ilk sırada sayılabilir. Dolayısıyla tarım ve su kaynakları gibi doğal sistemlerin bozulması, iklim krizinin gıda üretimi üzerindeki doğrudan etkilerini görünür kılarken; bu durum, gıda güvenliği sorununu daha da karmaşık hale getirmektedir. Tarımsal verimliliğin azalması, aşırı hava olaylarının artması, kuraklık ve su kıtlığı gibi ekolojik riskler, yerinden edilmelere ve zorunlu göç hareketlerine zemin hazırlamaktadır. Bu bağlamda, iklim değişikliği ve göç olgusu arasındaki kesişim, gıda güvenliğini çok yönlü bir biçimde tehdit eden temel dinamiklerden biri olarak öne çıkmaktadır. İklim krizinin nedenleri çok boyutlu olduğu gibi çözümünün de çok boyutlu olması, bu duruma dair problemin daha karmaşık ve giderilmesi zor bir hal kazanmasına yol açmaktadır.

Zorunlu ya da gönüllü nitelikteki göç hareketleri, göç veren ve hedef bölgelerin gıda sistemleri üzerinde baskı oluşturmaktadır. Özellikle kırsal alanlardan kent merkezlerine yönelen iç göç hareketleri, tarımsal üretimde işgücü kaybına yol açarken, kentlerde nüfusun yoğunlaşması ise gıda talebinin artmasına neden olmaktadır. Bu durum, mevcut gıda sistemlerinin sürdürülebilirliğini tehdit ederken, aynı zamanda toplumsal eşitsizlikleri derinleştirme potansiyeli taşımaktadır. Dolayısıyla, iklim krizine bağlı ekolojik dengenin bozulmasının tetiklediği göç süreçlerinin gıda güvenliği ile olan ilişkisini geniş bir perspektiften ele almak hem akademik hem de politika yapıcı çevreler için öncelikli bir gereklilik haline gelmiştir.

Kavramsal ve Teorik Çerçeve

Yerkürenin doğal ekolojik dengesinde, insan faaliyetlerine bağlı olarak ortaya çıkan hızlı, kapsamı geniş olan ve büyük çoğunlukla olumsuz değişimleri ifade etmektedir (IPCC, 2023). Bilindiği üzere Sanayi Devrimi'nde hızlı bir ivmeyle yoğunluk kazanan üretim ve bu üretim modellerine bağlı doğal kaynakların, özellikle fosil yakıtların, kullanımı yer altı ve yer üstü dengesine geri dönülemez zararlar vermiştir. Bu zararların başında, sera gazı emisyonlarının küresel sıcaklık artışına yol açması, normal yağış seyrinde kaymalara, kurak alanların genişlemesi ve tarımsal üretim istikrarının bozulmasına, yer altı sularının miktarının azalmasına

ve kirlenmesine neden olmuştur. Diğer taraftan doğal kaynakların kullanımının adilane paylaşılamaması, ekonomik ve sosyal tahsisin denge açığının büyümesine, söz konusu ekolojik dengesizliğin ve ekonomik sıkıntıların çeşitli coğrafyalarda insan hayatını ve ülkeler arası ilişkileri olumsuz etkilemesine sebep olmuştur. Bu olumsuzluk özellikle tarımsal üretime dayalı geçim sistemlerinin sürdürülebilirliğini tehdit eder hale gelmiş ve gıda güvenliğine yönelik olan doğrudan etkileri de yaratmaya devam etmektedir.

Gıda güvenliği ise, Birleşmiş Milletler Gıda ve Tarım Örgütü olan FAO tarafından, "herkesin her zaman, aktif ve sağlıklı bir yaşam sürmesi için gerekli olan yeterli güvenli ve besleyici gıdaya fiziksel, sosyal ve ekonomik erişiminin olması durumu" olarak tanımlanmaktadır (FAO, 2020). Gıda güvenliği tanımı içinde, küresel olarak birey ya da toplum ayrımı yapmadan bütün insanların, temiz ve besleyici gıdaya ulaşmak için; eşitlik, adillik ve güvenilirlik kavramlarını barındırmaktadır. Bu kavramlar günümüzün Toplum 5.0 felsefesinin tüm toplumlar için, eşit, adil, ulaşılabilir bir şekilde, ileri teknolojilerin tüm toplumların refahını sağlamak amacıyla kullanılması hedefi ile de örtüşmektedir. Bu sebeple gıda güvenliği; gıdaya erişme, gıda arzı, tüketim kalıplarının farklılıkları, doğal kaynakların sürdürülebilir kullanımı ve politik istikrar gibi pek çok bileşeni içermektedir.

Ekolojik dengenin bozulması ekonomik, sosyal ve politik birçok sonucu ortaya çıkarmaktadır. İnsanların yaşadıkları yerlerden geçici veya kalıcı olarak başka yerlere hareket etmesi olarak tanımlanan göç ise bunlardan birisidir (IOM, 2022). Göçlerin genel prensipte itici ve çekici yönleri mevcuttur ve çoğu zaman ekonomik, sosyal, politik ve iklime bağlı nedenlerle göç hareketleri tetiklenmektedir. İklime bağlı göçler ise, kuraklık, sel, toprak kaybı, yaşanılan bölgede geçim ve yaşam alanlarının sular altında kalması, doğal afetler gibi çevresel mecburiyetler nedeniyle yerlerinden ayrılmak zorunda kalan toplulukları ifade etmektedir. İklime bağlı göçler çoğunlukla isteğe bağlı olmayan göçler olarak nitelendirilebilir.

Gıda güvenliğinin sağlanamaması, özellikle kırılgan ve düşük gelirli topluluklarda yaşam koşullarını ağırlaştırarak göç kararlarını doğrudan etkileyebilmektedir (FAO, 2017). Özellikle kuraklık, toprak erozyonu ve gıda arzındaki istikrarsızlık gibi çevresel faktörler, tarımsal üretimi olumsuz etkileyerek göçü hızlandırmaktadır (Foresight, 2011). Öte yandan, göç hareketleri yerel gıda sistemleri üzerinde baskı oluşturabilmekte ve mevcut kaynakların dağılımında dengesizliklere yol açarak gıda güvensizliğinin artmasına sebep olabilmektedir (FAO ve IFAD, 2018). Göç alan bölgelerde artan nüfus, tarımsal üretim kapasitesini aşan talepler yaratmakta, bu da gıda arzının sürdürülebilirliğini tehdit etmektedir (Maxwell ve Smith, 1992). Sonuç olarak, göç ve gıda güvenliği arasındaki etkileşim karmaşık ve çok boyutlu olup, bu ilişkiyi anlamak sürdürülebilir kalkınma ve politika geliştirme süreçlerinde kritik önem taşımaktadır (Black vd., 2011; HLPE, 2017).

İklim krizi, göç ve ekonomi arasındaki ilişkiler, yalnızca çevresel değişimlere değil; aynı zamanda bu değişimlerin bireylerin ekonomik davranışları, geçim stratejileri ve toplumsal yapılar üzerindeki etkilerine de dayanmaktadır. Bu nedenle kuramsal olarak geniş bir çerçeve ile düşünülmeli, çevresel ekonomik ve toplumsal dinamiklerin kesiştiği noktalar dikkate alınmalıdır.

Çevresel Güvenlik ve Ekonomik Kırılganlık Yaklaşımı:

Çevresel bozulmaların devletlerin, toplumların ve bireylerin ekonomik ve fiziki güvenliklerini tehdit ettiği bir çerçeve sunmaktadır (Homer-Dixon, 1999). Bu yaklaşıma göre, iklim değişikliği ile artan kuraklık, sel, toprak erozyonu gibi olaylar özellikle tarım, hayvancılık ve balıkçılık gibi iklime duyarlı sektörlerde geçimini sağlayan toplulukların ekonomik

kırılganlığını artırmakta, bu da kitlesel göçleri tetiklemektedir. Örneğin Sahel bölgesinde tarımsal çöküşün göç dalgalarıyla nasıl ilişkilendiği bu perspektiften açıklanabilir (Brown vd., 2007).

Sürdürülebilir Geçim Kaynakları Yaklaşımı (Sustainable Livelihoods):

Geçim kaynaklarını sadece gelir odaklı değil; doğal (toprak, su), sosyal (ağlar), finansal (tasarruf, kredi), insan (eğitim, sağlık) ve fiziksel (altyapı) sermaye türleri üzerinden bütüncül biçimde ele almaktadır (Scoones, 1998). İklim değişikliğiyle birlikte, sermaye modellerinin çoğu tehdit altına girmektedir. Örneğin sulak alanların kuruması hem doğal sermayeyi hem de balıkçılıkla geçinen toplulukların ekonomik gelirini ortadan kaldırmakta, bu da göçü bir tek çıkar yol haline getirmektedir. Ekonomik güvenlikten yoksun bireylerin büyük çoğunluğu kırdan kente göç etmekte, bu da kentlerdeki gıda potansiyeline ilave yükler getirmektedir (Ellis, 2000).

Neo-Malthusyen Yaklaşım:

Neo-Malthusyen teoriye göre nüfus artışı, sınırlı doğal kaynaklarla birleştiğinde kıtlık, açlık, göç ve çatışmalara yol açabilmektedir. Bu yaklaşımda iklim değişikliği, doğal kaynaklar üzerindeki baskıyı artırarak ekolojik taşıma kapasitesini aşan nüfus hareketlerine neden olmaktadır (Ehrlich, Ehrlich, 1990). Göç burada hem bir sonuç hem de potansiyel bir kriz kaynağı olarak değerlendirilebilir. Bu teorik çerçevenin özellikle su kıtlığı, tarımsal üretimde azalma ve gıda fiyatlarındaki dalgalanmalar gibi ekonomik etkileri açıklamada kullanıldığı görülmektedir.

Ekolojik Ekonomi ve Adil Geçiş Yaklaşımı:

Ekonomiyi ekosistemlerin taşıma kapasitesi çerçevesinde yeniden tanımlayarak ve doğayla uyumlu bir üretim-tüketim modeli önermektedir (Daly, 1996). Bu bağlamda iklim kriziyle baş etmede yalnızca teknolojiye değil, üretim modellerinin dönüşümüne de ihtiyaç vardır. Söz konusu dönüşüm "Adil geçiş" (just transition) ilkesi ile açıklanmakta ve iklim politikalarının sosyal eşitsizlikleri artırmadan uygulanmasını öngörmektedir. Göçmen toplulukların, kırsal yoksulların ve iklimden doğrudan etkilenenlerin gıda güvenliğinin sağlanması, sadece insani değil aynı zamanda ekonomik sürdürülebilirlik açısından da kritiktir (ILO, 2015).

Göç Sistemleri Teorisi:

Göçün yalnızca bireysel değil, aynı zamanda yapısal ve sistemsel nedenlerle ortaya çıktığını savunmaktadır. Göç hareketleri, küresel ekonomik sistemler, işgücü piyasaları, ticaret ilişkileri ve iklimle etkileşimli olarak şekillenmektedir (Mabogunje, 1970). Örneğin iklim krizi nedeniyle tarım sektörünün çökmesi, kırsal işgücü fazlası yaratmakta, bu da kentlere göçü zorunlu kılmaktadır. Ancak kentlerdeki kayıt dışı ekonomi, gıda güvencesi sağlamakta yetersiz kalmakta ve yeni bir ekonomik dışlanmışlık döngüsü yaratmaktadır.

Politik Ekoloji ve İklim Adaleti Teorileri:

Çevresel sorunların doğal yapılarla beraber, politik ve ekonomik yapılarla da doğrudan ilişkili

olduğunu savunmaktadır (Robbins, 2012). Bu teoriye göre iklim krizinin etkileri eşit dağılmamaktadır; kırılgan ve yoksul topluluklar daha fazla etkilenmekte ve göçe zorlanmaktadır. İklim adaleti yaklaşımı da bu eşitsizliği vurgulayarak, özellikle gelişmiş ülkelerin tarihi sorumluluğuna dikkat çekerek ve gelişmekte olan ülkelerdeki gıda güvencesine yönelik destek politikalarının gerekliliğini ortaya koymaktadır (Schlosberg ve Collins, 2014). Bu teorik çerçeveler, iklim değişikliği-göç-gıda-ekonomi ilişkisini hem neden-sonuç ilişkileriyle hem de sistemsel dinamiklerle anlamlandırma açısından güçlü bir temel sunduğu söylenebilir. Analitik yaklaşımların disiplinler arası doğası, politika yapımında da kapsayıcı çözümler üretilmesine olanak tanımaktadır.

İklim Krizin ve Gıda Güvenliği İlişkisi

İklim krizi, insan faaliyetlerinin özellikle Sanayi Devriminden bu yana atmosfere saldığı sera gazları nedeniyle dünyanın iklim sisteminde meydana gelen düzensiz ve çoğu zaman geri döndürülemez değişiklikleri ifade edilen çevresel bir sorunu olarak düşünülebilir. İklim krizi, yalnızca bir çevre sorunu olarak değil; kalkınma, insan hakları, halk sağlığı, gıda güvenliği ve küresel eşitlik gibi çok çeşitli alanları etkileyen yapısal bir kriz olarak ele alınmalıdır. Bu nedenle çözümü de disiplinler arası bir yaklaşım, uluslararası iş birliği ve sürdürülebilir kalkınma ilkeleriyle uyumlu politik müdahaleler gerektirmektedir.

İklim, belirli bir bölgedeki sıcaklık, yağış, rüzgâr gibi meteorolojik değişkenlerin uzun yıllar boyunca gözlemlenen ortalamalarını ifade etmektedir (IPCC, 2021). Son yıllarda insan faaliyetlerinin etkisiyle bu iklimsel dengede gözle görülür sapmalar yaşanmakta ve bu durum literatürde "iklim krizi" olarak tanımlanmaktadır (Steffen vd., 2018).

Bu bağlamda iklim krizi çok boyutlu bir durumu ifade etmesi sebebiyle, yalnızca fiziksel iklim değişiklikleriyle sınırlı kalmamakta; aynı zamanda canlı türlerinin, ekolojik sistemlerin ve insan topluluklarının bu değişim karşısında adaptasyon kapasitelerinin zayıflamasıyla da doğrudan ilişkilendirilmektedir (Adger vd., 2005). İklim değişikliği artık öngörülebilir ve lineer bir süreç olarak değerlendirilmemekte; tersine, belirsizliklerin arttığı, uyum süreçlerinin zorlaştığı ve risklerin toplumsal sistemleri tehdit ettiği bir "kriz durumu" olarak ele alınmaktadır (UNEP, 2022). Bu nedenle "iklim krizi" kavramı, sadece bir çevresel durumu tanımlamakla kalmayıp aynı zamanda küresel düzeyde acil, bütüncül ve kalıcı politika müdahalelerinin gerekliliğine dikkat çeken normatif bir çağrı niteliği de taşımaktadır (Klein, 2014). Küresel ortalama sıcaklıklardaki artış; deniz seviyelerinin yükselmesi, buzulların erimesi, ekstrem hava olaylarının (kuraklık, sel, orman yangınları vb.) artışı ve tarımsal üretkenliğin azalması gibi çeşitli etkileri beraberinde getirmektedir. Bu etkiler yalnızca çevresel olmasının yanı sıra ekonomik eşitsizlikleri derinleştiren, iklim adaleti tartışmalarını gündeme taşıyan ve küresel yönetişim mekanizmalarının yetersizliğini görünür kılan sosyo-politik sonuçlar doğurmaktadır.

Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi (UNFCCC), iklim değişikliğini şu şekilde tanımlar: "İklim değişikliği, karşılaştırılabilir bir zaman diliminde doğal iklim değişkenliğine ek olarak, doğrudan ya da dolaylı insan faaliyetleri sonucu küresel atmosferin bileşiminde meydana gelen değişiklikleri ifade eder." (BM, 1992). Bu tanımda özellikle dikkat çeken husus, "iklim değişikliği" kavramının sadece doğal süreçlerle sınırlı tutulmaması; aynı zamanda insan kaynaklı etkilerin, özellikle sera gazı emisyonlarının, bu değişimi hızlandıran temel unsurlar olarak vurgulanmasıdır. Bu yaklaşım, insan etkisini merkeze alan bilimsel ve politik bir çerçeve sunar. Bu yönüyle sözleşme, "doğal iklim değişkenliği" ile "insan faaliyetlerinden kaynaklanan iklim değişikliği" arasında açık bir ayrım yapmaktadır. Dolayısıyla iklim değişikliği, insanlığın küresel atmosfer üzerindeki etkisini göz önünde

bulunduran ve bu etkiyi doğrudan politika üretiminin merkezine yerleştiren bir kavram olarak ele alınmaktadır. Bu tanım, sözleşmenin temelini oluşturarak iklim değişikliğiyle mücadelede yükümlülüklerin belirlenmesine zemin hazırlar. İklim değişikliği yaşandığı süreç itibari ile birçok değişikliğe sebep olmaktadır bunların içinde insanların ve canlıların topluluk halinde göç etmesidir. Göçlere sebep olan faktörler sadece savaş veya istihdam değildir. Güvenli gıdaya erişime sahip olmak içinde göç edilebilmektedir.

İklim temelli göç, çoğu zaman yavaş gelişen çevresel değişimlerin tarımsal üretimi ve geçim kaynaklarını olumsuz etkilemesi sonucunda ortaya çıkmakta; bu da özellikle kırsal kesimlerde yaşayan toplulukların yer değiştirme kararlarını tetiklemektedir (Black et al., 2011). Uluslararası literatürde bu tür hareketlilikler "çevresel göç" ya da "iklim mülteciliği" kavramlarıyla tanımlansa da, bu olgunun hukuki statüsü halen belirsizdir (McAdam, 2012). Birleşmiş Milletler Mülteciler Yüksek Komiserliği (UNHCR), iklim değişikliğine bağlı olarak yerinden edilen bireylerin, geleneksel mülteci tanımı kapsamına girmediğini ancak korunma ihtiyacının giderek arttığını vurgulamaktadır (UNHCR, 2021). İklim krizinin göç üzerindeki etkileri, yalnızca göç veren bölgelerde değil; göç alan bölgelerde de gıda güvenliği, işgücü dengesi ve altyapı kapasiteleri açısından ciddi baskılar yaratmaktadır. Dolayısıyla, iklim temelli göç hareketleri hem çevresel hem de sosyal politika alanlarında çok disiplinli bir yaklaşımla ele alınması gereken küresel bir çözüm arayışı olarak nitelendirilebilir.

İklim krizi, tarımsal üretim sistemleri üzerinde doğrudan ve dolaylı etkiler yaratarak gıda güvenliğini çok yönlü bir biçimde tehdit etmektedir. Artan sıcaklıklar, değişen yağış rejimleri, kuraklık, sel ve diğer aşırı hava olayları, özellikle kırılgan ekosistemlerde tarımsal verimliliği düşürmekte ve üretim sürekliliğini sekteye uğratmaktadır (FAO, 2017). Bu durum, yalnızca üretim düzeyinde değil; aynı zamanda gıdaya erişim, kullanım ve istikrar boyutlarında da ciddi sorunlar doğurmaktadır. Özellikle düşük ve orta gelirli ülkelerde iklim değişikliği, kırsal yoksulluğu derinleştirerek hem üretici hem de tüketici açısından gıda güvencesini zayıflatmaktadır (IPCC, 2022). Dolayısıyla iklim krizine karşı geliştirilecek politika ve stratejiler, çevre, sosyal adalet ve sürdürülebilir kalkınma ilkeleriyle de uyumlu olması gerekmektedir.

Gıda güvenliği, bireylerin sağlıklı ve aktif bir yaşam sürdürebilmesi için fiziksel, sosyal ve ekonomik olarak yeterli, güvenli ve besleyici gıdaya her zaman erişebilmesi durumu olarak tanımlanmaktadır. Bu kavram, gıdanın mevcut olup olmamasını, bu gıdanın erişilebilirliğini, kullanılabilirliğini ve sürdürülebilirliğini de kapsamaktadır (FAO, 2017). Birleşmiş Milletler Gıda ve Tarım Örgütü'ne (FAO) göre gıda güvenliği dört temel boyut üzerinden değerlendirilmektedir; Gıda arzının yeterliliği (mevcudiyet): Yeterli miktarda gıdanın üretilmesi ve tedarik edilmesi. Erişim: Bireylerin bu gıdaya ekonomik ve fiziksel olarak ulaşabilmesi. Kullanım: Gıdanın besin değeri, hijyenik koşullarda hazırlanması ve sağlıklı tüketimi. İstikrar: Bu üç unsurun sürekliliğinin sağlanması, ani şoklardan (iklim, ekonomik kriz, savaş vb.) etkilenmemesi.

Gıda güvenliği, yoksulluk, eşitsizlik, çevresel sürdürülebilirlik, iklim değişikliği ve gıda sistemlerinin yönetimiyle bağlantılı olduğu için, gıda güvenliği konusu disiplinlerarası bir yaklaşımla ele alınmakta ve hem ulusal hem de küresel düzeyde politika geliştirme süreçlerinin merkezinde yer almaktadır. İklim değişikliğinin göçlere sebep olma niteliği ve gıda üretimi ve erişilebilirliğine verdiği tahribat kaçınılmaz bir gerçekliktir. Güvenli gıda kavramını kullanırken burada bahsettiğimiz gıda kavramının içine su tüketimindeki güvensiz kullanımı eklediğini de belirtmek gerekmektedir.

Gıda güvencesi ve gıda güvenliği kavramları, zaman içerisinde hem içerik hem de kapsam açısından gelişmiş ve giderek birbiriyle daha bütüncül şekilde ele alınmaya başlanmıştır. Bu

çerçevede, Birleşmiş Milletler İnsan Hakları Evrensel Beyannamesi'nde (1948) gıdaya erişim, insanın en temel haklarından biri olarak tanımlanmış; böylece gıda hakkı, uluslararası insan hakları hukukunun temel ilkelerinden biri haline gelmiştir. 1970'li yıllara gelindiğinde ise küresel ölçekte artan gıda ve beslenme sorunları, bu alandaki politika tartışmalarını hızlandırmış ve 1974 yılında gerçekleştirilen Dünya Gıda Konferansı, bu tartışmaların dönüm noktası olmuştur. Konferansta yapılan tanımlamada, gıda güvencesi (food security) kavramı büyük ölçüde arz merkezli bir yaklaşımla ele alınmış; temel gıda maddelerinin dünya genelinde, gıda tüketimindeki sürekli artışı karşılayabilecek düzeyde ve fiyat dalgalanmalarına karşı istikrarlı bir şekilde erişilebilir olmasına vurgu yapılmıştır (United Nations [UN], 1975; Food and Agriculture Organization of the United Nations [FAO], 2003). Bu tanım, dönemin ekonomik ve politik öncelikleri doğrultusunda, gıda üretimi ve küresel tedarik zincirinin sürdürülebilirliğine odaklanan bir yaklaşımı yansıtmaktadır.

Birleşmiş Milletler Gıda ve Tarım Örgütü'nün (FAO) 2001 tarihli Dünyadaki Gıda Güvensizliğinin Durumu başlıklı yıllık raporunda, gıda güvenliği kavramı; "tüm bireylerin, her zaman aktif ve sağlıklı bir yaşam sürdürebilmek için gerekli olan beslenme gereksinimlerini ve gıda tercihlerini karşılayacak yeterli, güvenli ve besleyici gıdaya fiziksel, sosyal ve ekonomik açıdan erişebildiği durum" olarak tanımlanmıştır (FAO, 2002:5). Bu doğrultuda, gıda güvenliği kavramı zamanla "gıda güvenliği ve beslenme" başlığı altında daha geniş kapsamlı bir çerçevenin alt bileşeni olarak değerlendirilmeye başlanmıştır. 2000'li yıllara gelindiğinde ise, gıda güvenliği tartışmalarına yoksulluk unsurunun da dâhil edilmesi gerektiği vurgulanmış; ancak yalnızca yoksulluğun ortadan kaldırılmasının, gıda güvenliğinin tam anlamıyla sağlanması için yeterli bir koşul olmadığı genel kabul görmüştür.

İklim değişikliği, tarımsal üretimi ve su kaynaklarını doğrudan etkileyerek hem gıda güvencesini hem de zorunlu göç hareketlerini tetikleyen çok yönlü bir kriz dinamiği haline gelmiştir. Artan sıcaklıklar, azalan yağış rejimleri ve su kıtlığı, özellikle yağışa bağımlı tarım yapılan bölgelerde ürün verimliliğini ciddi biçimde düşürmektedir (FAO, 2021). Buna bağlı olarak yaşanan tarımsal üretim kayıpları, kırsal nüfusun geçim kaynaklarını tehdit etmekte; ekonomik yoksunluk ve gıdaya erişimdeki kısıtlılıklar, toplulukları göçe zorlayan temel faktörler arasında yer almaktadır (IOM, 2022).

Özellikle kuraklık, sel ve fırtına gibi iklim kaynaklı afetlerin sıklığı ve şiddetindeki artış, yerleşim alanlarının fiziksel olarak tahrip olmasına neden olmakta ve gıda üretimini aksatmaktadır (IPCC, 2022). Bu koşullar altında gıdanın hem fiziksel hem de ekonomik erişilebilirliği azalmış; düşük gelirli ve kırılgan gruplar, bu süreçten orantısız biçimde etkilenmiştir. Dolayısıyla, iklim değişikliği sadece çevresel değil; aynı zamanda sosyal adalet, kalkınma ve insan hakları alanlarında da çok boyutlu sonuçlar doğurmaktadır (Cissé vd., 2022). Gıda güvenliği, bireylerin yeterli, dengeli ve sağlıklı beslenme olanaklarına sürekli erişimini sağlamada temel bir unsur olarak öne çıkmaktadır. Gıda güvencesinin sağlanamaması durumunda, özellikle düşük gelirli gruplarda yetersiz beslenme, mikrobesin eksiklikleri ve beslenmeye bağlı hastalıklar yaygınlaşmaktadır (FAO, IFAD, UNICEF, WFP ve WHO, 2023). Gıda güvenliği yalnızca kalori alımını değil, aynı zamanda besin değeri yüksek, çeşitli ve güvenilir gıdalara ulaşımı da içermektedir. Bu nedenle, gıda güvenliği ile yeterli ve dengeli beslenme arasında doğrudan ve karşılıklı bir ilişki söz konusudur (WHO, 2020).

Göç Hareketliliği ve İklim Krizi: Çift Taraflı Etkileşim

Toplumların kuruluşundan bu zamana kadar göç, insanın hayatta kalabilme mücadelesi sürecinde devam etmektedir. Dolayısıyla göç hareketleri insanlık tarihinde sürekli var olan bir

eylemdir. Göç bireysel veya toplu olarak gerçekleşebileceği gibi, nedenleri arasında güvenli alana geçme ve ekonomik olarak varlığını devam ettirebilme veya gıda ve suya ulaşabilme yatabilmektedir.

Bu açıdan göç, bireylerin ya da toplulukların farklı nedenlerle yer değiştirmesini ifade ederken, bu hareketler çeşitli ölçütlere göre sınıflandırılabilmektedir. En yaygın ayrım iç göç ve dış göç (uluslararası göç) şeklindedir. İç göç, bireylerin aynı ülke sınırları içerisinde, genellikle kırsaldan kente doğru yaptığı yer değişimini ifade ederken; dış göç, bir ülkeden başka bir ülkeye gerçekleşen sınır aşan hareketleri kapsar (İçduygu, 2015). Bunun yanında, gönüllü göç (ekonomik nedenlerle yapılan) ve zorunlu göç (savaş, doğal afet, siyasi baskı gibi nedenlerle yapılan) ayrımı da yapılmaktadır (Kaya, 2018). Ayrıca göç, süresine göre de geçici veya kalıcı olarak sınıflandırılabilmektedir. Günümüzde özellikle iklim değişikliği, çatışmalar ve ekonomik eşitsizlikler gibi etkenler, farklı göç türlerinin iç içe geçmesine neden olmakta ve bu olguyu çok boyutlu bir hale getirmektedir.

Son yıllarda göçün boyutlarından birini oluşturan iklim değişikliği, göç hareketliliğini tetikleyen çevresel faktörler arasında giderek daha belirgin bir yer edinmektedir. Artan sıcaklıklar, kuraklık, çölleşme, sel ve fırtına gibi aşırı hava olayları, özellikle tarım ve su kaynaklarına bağımlı toplulukların yaşam koşullarını doğrudan tehdit etmekte; bu durum bireylerin yaşadıkları yerleri terk etmelerine neden olmaktadır (Türkeş, 2020). Nitekim Birleşmiş Milletlere göre iklim değişikliği, 21. yüzyılda zorunlu göçün başlıca sebeplerinden biri haline gelmiştir (Keleş, 2021). Bu çerçevede, iklim değişikliğinin yalnızca çevresel değil; aynı zamanda sosyoekonomik ve demografik etkiler doğurarak göç olgusunu çok yönlü hale getirdiği görülmektedir.

İklim krizi ile göç hareketliliği arasındaki ilişki, tek yönlü bir nedensellikten ziyade karşılıklı ve dinamik bir etkileşim biçiminde ortaya çıkmaktadır. Bir yandan, iklim değişikliğinin neden olduğu çevresel bozulmalar—kuraklık, sel, çölleşme ve deniz seviyesi yükselmesi gibi faktörler—tarımsal üretimi, geçim kaynaklarını ve yaşam koşullarını tehdit ederek bireyleri yer değiştirmeye zorlamakta; böylece göç hareketliliği üzerinde doğrudan bir baskı oluşturmaktadır (IOM, 2022; IPCC, 2022). Bu çift yönlü ilişki, iklim değişikliği ve göç arasında hem nedensel hem de sonuçsal bir bağlantı bulunduğunu göstermekte; dolayısıyla bu iki olgunun ayrı ayrı değil, bütüncül politikalarla birlikte ele alınması gerekliliğini ortaya koymaktadır.

Göç hareketliliği, yalnızca iklim krizinin bir sonucu olarak ortaya çıkmaz; aynı zamanda bu krizi derinleştiren dolaylı bir etki alanına da sahiptir. Özellikle iklimsel nedenlerle yerinden olan bireylerin yoğun olarak kentlere göç etmesi, altyapı sistemleri üzerinde baskı oluşturmakta ve plansız kentleşme, artan enerji tüketimi, atık üretimi ve doğal kaynakların aşırı kullanımı gibi çevresel sorunlara yol açmaktadır (Keleş, 2021). Bu durum, karbon salımını artırarak ve ekosistemleri baskı altına alarak iklim krizini daha karmaşık ve çok boyutlu hale getirmektedir. Ayrıca göçmen toplulukların yaşadığı alanlarda orman tahribatı, arazi kullanımında değişim ve su kaynaklarının tükenmesi gibi süreçler de, göçün çevresel etkilerini büyütmektedir (IOM, 2022). Dolayısıyla göç, yalnızca iklim değişikliğinden etkilenen bir süreç değil, aynı zamanda kriz döngüsünü tetikleyen bir unsur olarak da değerlendirilmelidir. Dolayısıyla göç ve iklim krizi arasında kümülatif bir etki olduğu söylenilebilmektedir.

Küresel iklim krizi, sıcaklık artışları, düzensiz yağış rejimleri ve ekstrem hava olaylarının sıklığı nedeniyle tarımsal üretimi olumsuz etkileyerek gıda arzında dengesizliğe sebep olduğu artık bilinen bir gerçektir (IPCC, 2022). Kuraklık, sel ve don olayları, başta temel gıda ürünleri olmak üzere üretim kayıplarına neden olmakta, bu da gıda fiyatlarının volatilitesini artırarak düşük gelirli kesimlerin beslenme güvenliğini tehdit etmektedir (FAO, 2017). Gıda fiyatlarındaki dalgalanmalar yoksul ve kırılgan grupların beslenme güvenliğini tehdit etmekte,

yoksulluğun artmasına neden olmaktadır (UNDP, 2020; Wheeler ve von Braun, 2013). Özellikle Afrika, Güney Asya ve Orta Doğu gibi kırılgan bölgelerde açlık ve yetersiz beslenme riski ciddi boyutlara ulaşmıştır (Wheeler ve von Braun, 2013).

İklim değişikliğinin bir diğer kritik etkisi su döngüsünde yaratılan bozulmadır. Azalan yağışlar, hızlanan buharlaşma ve su kaynaklarının kirlenmesi, dünya genelinde su kıtlığı riskini büyütmektedir (IPCC, 2022). Su, tarımsal üretim için vazgeçilmez bir kaynak olduğundan, su kıtlığı tarımsal üretim ve dolayısıyla gıda güvenliği üzerinde doğrudan olumsuz etkiler yaratmaktadır (FAO, 2017).

Türkiye'de ise özellikle İç Anadolu ve Güneydoğu Anadolu bölgelerinde artan sıcaklıklar ve azalan yağışlar tarımsal verimliliği düşürmekte, kuraklık riski gıda üretiminde doğrudan kayıplara yol açmaktadır (TÜBİTAK, 2021). Sulama altyapısının yetersizliği ve suyun verimsiz kullanımı bu riski daha da artırmaktadır (DİE, 2020). Türkiye'de tarım sektörü, ülke ekonomisinin önemli bir parçası olmasına rağmen, iklim değişikliğinin getirdiği risklerle birlikte kırılgan hale gelmiştir. Bölgesel ekonomik dengesizlikler, özellikle göç veren bölgelerde yoksulluğun artmasına ve sosyal sorunların büyümesine zemin hazırlamaktadır (Ulucak, 2023). Türkiye'de su kaynaklarının bölgesel dağılımında dengesizlikler ve nüfus artışı, suyun tarım dışı sektörlerde de yoğun kullanımına yol açarak, tarımsal su güvenliğini tehdit etmektedir (TÜBİTAK, 2021). Özellikle kuraklık dönemlerinde suyun yetersizliği tarımda verim kaybına sebep olmakta ve gıda fiyatlarında dalgalanmalara neden olmaktadır (Paçacı, 2019). Bu durum, gıda güvenliği açısından da risk teşkil etmektedir; göç eden ve göç alan topluluklar arasında beslenme kalitesinde düşüşler yaşanabilir, yerel gıda talebi ve arzı arasındaki dengesizlikler beslenme güvensizliğine yol açabilir (McMichael, 2017).

İklim kaynaklı çevresel değişiklikler, insanların yaşadıkları yerlerden zorunlu göç etmelerine neden olmaktadır (Black ve ark., 2011). Bu göç hareketleri hem kaynak bölgelerde ekonomik ve sosyal yapının bozulmasına, hem de göç alan bölgelerde altyapı, barınma ve hizmetlerin yetersiz kalmasına yol açmaktadır (Rigaud ve ark., 2018). Türkiye gibi transit ve hedef ülke konumundaki ülkelerde, iklim göçü ile beraber gelen mülteci akınları sosyal uyum, iş gücü piyasası ve kamu hizmetleri üzerinde baskı oluşturmakta ve toplumsal gerilimleri artırmaktadır (Çalışkan, 2021). İklim krizi ve göç, gıda güvenliği üzerinde çok boyutlu ve karmaşık riskler yaratmaktadır. Bu riskler, yalnızca üretim ve arzı değil; aynı zamanda sosyal yapıyı, ekonomik istikrarı ve çevresel sürdürülebilirliği de tehdit etmektedir. Bu bağlamda iklim değişikliğine uyum stratejilerinin güçlendirilmesi, göç yönetiminde kapsamlı politikalar geliştirilmesi ve su-gıda güvenliği alanında önleyici tedbirler alması kritik önem taşımaktadır.

İklim değişikliği, gıda güvenliği ve göçle ilişkili sağlık risklerini de beraberinde getirmektedir. Beslenme yetersizliği, özellikle çocuklar ve yaşlılar arasında sağlık sorunlarını artırmakta, iklim değişikliğinin tetiklediği bulaşıcı hastalıklar ve su kaynaklı hastalıklar sağlık sistemleri üzerinde ek yük oluşturmaktadır (Watts vd., 2018). Göç nedeniyle yer değiştiren topluluklarda sağlık hizmetlerine erişim sorunları artmakta, bu da sağlık risklerini büyütmektedir.

İklim krizi ile birlikte yaşanan ormansızlaşma, toprak erozyonu, biyoçeşitlilik kaybı ve ekosistemlerin bozulması, tarımsal üretim alanlarını azaltmakta, doğal kaynakların sürdürülebilir kullanımını zorlaştırmaktadır (IPBES, 2019). Türkiye'de özellikle Doğu Anadolu ve Akdeniz bölgelerinde bu riskler yoğunlaşmaktadır (TÜBİTAK, 2021).

İklim değişikliği ve buna bağlı kaynak kıtlıkları, göç hareketleri ve ekonomik bozulmalar, siyasi istikrarı tehdit eden unsurlar olarak ortaya çıkmaktadır (UNDP, 2020). Bölgesel çatışmalar, özellikle sınır bölgelerinde göçmen ve mülteci krizleriyle birleşince, ulusal güvenlik risklerini artırmaktadır (Çalışkan, 2021). Bu durum, sürdürülebilir gıda güvenliği için gerekli

olan uzun vadeli politikaların oluşturulmasını zorlaştırmaktadır.

Politika ve Stratejik Yaklaşımlar, Riskler

İklim değişikliği, göç ve gıda güvenliği alanları birbirinden ayrı düşünülemez. Bu nedenle, politika yapıcıların ilgili tüm sektörleri (tarım, çevre, göç, kalkınma, sağlık vb.) kapsayan, entegre ve çok disiplinli politika çerçeveleri geliştirmeleri gerekmektedir (FAO, 2021). Sadece çevresel önlemler değil, aynı zamanda sosyal ve ekonomik boyutları da dikkate alan bütüncül yaklaşımlar, krizin etkilerini azaltmada etkin olacaktır. Bu kapsamda ulusal stratejilerle uyumlu yerel uygulamalar teşvik edilmesi gerekmektedir.

İklim değişikliğine bağlı olumsuz etkileri azaltmak için, göç veren bölgelerde iklim adaptasyon kapasitesinin güçlendirilmesi üzerinde durulması gereken bir uygulama olarak karşımıza çıkmaktadır. Bu açıdan su kaynaklarının sürdürülebilir yönetimi, erozyon kontrolü, kuraklığa dayanıklı bitki türleri, modern tarım teknikleri ve agroekolojik uygulamalar desteklenmelidir (IPCC, 2022). Bu tür uygulamalarla iklime adaptasyonun sağlanması ve değişen şartlara karşı yerinde kalma amacını sağlayabilmek için ekonomik ve sosyal dayanıklılığın artırılması gerekli olan yaklaşımlardan birisi olarak kabul edilmektedir. Ayrıca, tarımsal altyapının güçlendirilmesi ve teknolojik yeniliklerin yaygınlaştırılması, üretkenliği artırarak göç baskısını azaltıcı etki yaratabilir.

Göç, uyum ve entegrasyon süreçleriyle birlikte yönetilmelidir. Göç alan bölgelerde konut, eğitim, sağlık ve istihdam politikalarının geliştirilmesi, göçmenlerin sosyal uyumunu kolaylaştıracaktır (McMichael, 2017). Sosyal dışlanma ve işsizlik riskleri azaltılmalı, göçmenlerin yerel ekonomiye entegrasyonunu destekleyecek mesleki eğitim ve kapasite geliştirme programları uygulanmalıdır. Bu, gıda üretimi ve dağıtımı zincirlerinin sürdürülebilirliğine olumlu katkılar sağlayacaktır. Bu bağlamda göçün yönetimi ve entegrasyon politikaları önem arz etmektedir.

İklim değişikliği kaynaklı göç hareketlerini ve gıda güvenliği risklerini önceden tahmin etmek için erken uyarı sistemleri kurularak uygulanması oldukça önemlidir (Rigaud ve vd., 2018). Meteorolojik, tarımsal ve sosyal göstergelerin entegre edildiği dinamik veri tabanları ve analitik modeller, krizlerin önceden tespiti ve müdahalesini mümkün kılarak zararların azaltılmasına yardımcı olabilecektir. Bu sistemler politika yapıcıların hızlı ve etkili kararlar almasını sağlaması kuvvetle muhtemeldir.

İklim değişikliği ve göçün etkileri ulusal sınırları aşan nitelikte olduğundan, uluslararası iş birliği zorunlu hale gelmiştir. Gelişmekte olan ülkelerde, iklim değişikliğine bağlı göç ve gıda güvenliği sorunlarını azaltmak amacıyla finansal destek mekanizmaları (Yeşil İklim Fonu, Adaptasyon Fonu vb.) güçlendirilmelidir (UNFCCC, 2023). Teknik bilgi paylaşımı ve kapasite geliştirme projeleri teşvik edilerek, bölgesel ve uluslararası hatta küresel iş birlikleri, ortak risk yönetimi stratejileri geliştirilerek dayanıklılığın artırılması sağlanabilecektir.

Göçlerin azaltılması veya göç sebebiyle oluşan sorunların çözülebilmesi için politika süreçlerine, göçmenler, yerel halk, sivil toplum ve akademi gibi tüm paydaşların katılımı sağlanmalıdır (FAO, 2021). Kapsayıcı ve katılımcı bir yönetim modeli temelli uygulanan stratejilerin yerel ihtiyaçlara uygunluğunu ve sürdürülebilirliğini katkı sağlayacaktır. Toplumsal farkındalık kampanyaları ile iklim değişikliği ve göçün etkileri hakkında ortak bir bilincin oluşturulması ve bu konuda uygulanacak yapıcı tüm politikaların uyumunun sağlanması olası olumsuz sonuçları bertaraf edebilecektir.

Gıda güvenliğini sağlamak için, sadece üretim artırımı değil, aynı zamanda gıda sistemlerinin

dayanıklılığı ve çeşitliliği önceliklendirilmelidir (FAO, 2017). Yerel gıda üretiminin desteklenmesi, gıda israfının azaltılması ve sürdürülebilir tüketim alışkanlıklarının teşviki önem arz etmektedir. Tarımsal üretimde iklim dostu tekniklerin yaygınlaştırılması, gıda arz zincirinin iklim şoklarına karşı dirençli hale getirilmesi ile sürdürülebilir bir gıda sistemi ve gıda ürünü çeşitliliğinin artırılması sağlanabilir. Diğer taraftan göçü azaltmak ve kırsal kalkınmayı desteklemek için, tarım dışı alternatif gelir kaynakları geliştirilmelidir. Kırsal turizm, küçük ölçekli işletmeler, yenilenebilir enerji projeleri gibi alanlar hem ekonomik çeşitliliği artıracak hem de göç baskısını hafifletecektir (McLeman, 2018).

Sonuç

Günümüzde iklim değişikliği, toplumlar üzerinde giderek çok boyutlu etkiler oluşturmaktadır. Bu durum, canlıların geçici ya da kalıcı biçimlerde yaşadıkları yerleri terk etmelerine neden olmaktadır. Ancak uluslararası hukukta iklim nedeniyle yaşanan yer değiştirmeler hala hukuksal zemine oturmamaktadır. Literatürde bu bireyler sıklıkla "iklim mültecisi" olarak tanımlansa da 1951 Cenevre Sözleşmesi'nin dar yorumlanan mültecilik tanımı, çevresel nedenlerle göç edenleri bu kapsama dahil etmemektedir (Biermann ve Boas, 2010: 67). Bu dahil edilmeyiş birçok hukuksal boşluğu doğurmaktadır. Bu durumun başlıca nedenlerinden biri, çevresel göçün ekonomik, sosyal ve siyasal unsurlarla iç içe geçmiş çok boyutlu yapısıdır (Black et al., 2011). Ayrıca, iklim değişikliği nedeniyle yerinden edilen kişi sayısındaki artışa rağmen, özellikle gelişmiş ülkelerdeki politika yapıcıların bu soruna yönelik ilgisizliği dikkat çekmektedir (Bilici, 2021: 87). Öte yandan, mevcut uluslararası hukukta mülteci statüsünün yalnızca ülke sınırlarını aşan göçleri kapsaması, bununla birlikte iklime bağlı yer değiştirmelerin büyük kısmının ülke içi hareketler şeklinde gerçekleşmesi, bu bireylerin hukuki tanımlanmasını daha da karmaşık hale getirmektedir (McAdam, 2012). Dolayısıyla, iklim mülteciliği kavramının hukuki bir zemine oturtulamaması hem kavramsal belirsizliklere hem de veri toplama, izleme ve koruma mekanizmalarının eksikliğine yol açmaktadır.

Göç olgusu, küreselleşmenin de etkisiyle yalnızca göç alan ülkeleri değil, dünya genelindeki birçok devleti ilgilendiren çok boyutlu bir mesele haline gelmiştir. Bu durum, özellikle göçmenlere yönelik toplumsal algının olumsuzlaştığı bazı ülkelerde ciddi bir göç krizine dönüşmekte ve göçmenlerin topluma entegrasyonunu zorlaştırmaktadır (Castles, de Haas & Miller, 2014). Birçok ülke göçmenlere yönelik güvenlik temelli politikaları önceliklendirirken, bunun yerine sosyal ve ekonomik entegrasyonu önceleyen daha kapsayıcı politikalara ihtiyaç duyulmaktadır. Bu bağlamda, uluslararası düzeyde farkındalığın artırılması, finansal destek mekanizmalarının güçlendirilmesi ve sürdürülebilir entegrasyon programlarının geliştirilmesi elzemdir (Betts & Collier, 2017).

Özellikle iklim değişikliğinin etkileriyle karşı karşıya kalan kırılgan ülkelerin uyum kapasitelerini desteklemek amacıyla "İklim Mültecilerinin Korunması ve Yeniden Yerleştirme Fonu" gibi çok taraflı finansal yapıların kurulması gerekmektedir (Biermann & Boas, 2010). Sanayileşmiş ülkeler, tarihsel sorumlulukları ve ahlaki yükümlülükleri doğrultusunda bu maliyetleri paylaşmalı ve savunmasız ülkelere yapısal destek sağlamalıdır (Roberts & Park, 2007). İklim mültecileri bağlamındaki söylemler, sadece siyasal ve ekonomik tartışmalarla sınırlı kalmamalı; bu kişiler küresel iklim adaletinin bir parçası olarak görülmelidir. Ayrıca, iklim değişikliğine bağlı olarak yerinden edilme riski taşıyan bölgeler için uzun vadeli göç stratejilerinin geliştirilmesi ve 1951 Cenevre Sözleşmesi'nin iklim göçmenlerini de kapsayacak şekilde revize edilmesi, bu alandaki temel hukuki boşlukların giderilmesi açısından büyük önem taşımaktadır (McAdam, 2012; Zickgraf, 2021).

İklim krizi, günümüzde sadece çevresel bir tehdit olmanın ötesinde, sosyoekonomik kırılganlıkları derinleştiren, kitlesel göçleri tetikleyen ve özellikle gıda güvenliği üzerinde ciddi etkiler yaratan küresel bir mesele haline gelmiştir. Bu çalışmada, iklim değişikliği ile göç arasındaki karşılıklı etkileşimler ve bu sürecin gıda üretimi, dağıtımı ve erişimi üzerindeki yansımaları analiz edilmiştir. Özellikle kırılgan ekosistemlerde yaşanan çevresel bozulmaların, tarım arazilerinin verimsizleşmesine, su kaynaklarının tükenmesine ve geçim kaynaklarının kaybına yol açtığı; bu durumun ise toplulukları yer değiştirmeye zorladığı vurgulanmıştır. Göçün arttığı bölgelerde altyapı baskısı, gıda arzında yetersizlik ve sosyal hizmetlerde tıkanmalar gibi sorunlar, gıda güvenliğini daha da kırılgan hale getirmektedir.

Çok katmanlı krize karşı etkili ve bütüncül çözümler geliştirilmesi, yalnızca iklim politikalarıyla değil, aynı zamanda göç ve tarım politikalarıyla da entegre edilmelidir. Gıda sistemlerinin dayanıklılığını artıracak, iklime uyumlu tarım tekniklerini destekleyecek ve göçmen toplulukların sosyal ve ekonomik entegrasyonunu kolaylaştıracak stratejiler öncelik kazanmalıdır. Bu bağlamda, uluslararası iş birliği mekanizmalarının güçlendirilmesi, savunmasız ülkeler için finansal ve teknik destek sağlanması ve iklim mültecilerine dair hukuki tanımın yeniden ele alınması gerekmektedir. Aynı zamanda yerel yönetimlerin, iklim kaynaklı göç hareketlerine hazırlıklı olabilmesi için erken uyarı sistemleri, afet risk azaltım stratejileri ve gıda güvenliği politikaları bütünleşik şekilde kurgulanmalıdır.

Sonuç olarak, iklim kriziyle birlikte derinleşen göç dinamikleri ve bunun gıda güvenliği üzerindeki yansımaları, sürdürülebilir kalkınma hedeflerini doğrudan tehdit etmektedir. Bu nedenle, çevresel adalet, sosyal dayanışma ve uluslararası sorumluluk ilkeleri doğrultusunda geliştirilecek politika ve stratejik yaklaşımlar, yalnızca bugünün krizlerine değil, geleceğin gıda ve yaşam güvencelerine de katkı sağlayacaktır. Bu şekilde hayata geçirilecek uygulamalar, uzun vadede hem sürdürülebilirliğe hem de güvenli gıda üretimine eş zamanlı olarak katkı sağlayacak; aynı zamanda gıda sistemlerinin üzerindeki baskının azalmasına yardımcı olacaktır.

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HYBRID MANAGEMENT IN HEALTHCARE

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ABSTRACT

This study aims to emphasize hybrid management in the health sector. In hybrid management, the professionalism that the manager has gained from the job he/she has been trained for and the corporate business identity that he/she has gained from the institution he/she works for are together. In the background, there are factors such as informal relations, mandatory situations, acquaintances and being deemed appropriate. However, assignments should be made by taking into consideration merit, work experience, expertise and fairness so that competent people can contribute to the institution.

Hybrid managers are frequently encountered in health institutions. Because medical education is popular, doctors are always in the foreground. Therefore, the management of health institutions is generally carried out by physicians. As a result, physicians try to cope with management problems outside their branches. There is a lack of knowledge, especially in financial matters and mastery of legislation. However, health management is a specific discipline that includes a different knowledge accumulation than the skills of a physician. In order to ensure the desired level of efficiency and quality in health service delivery, health institutions should be managed by professionals who have received training in this field. Because health service providers are specialized and complex structures that include many departments, have an uninterrupted process and where human relations and communication are very important. On the other hand, it is obvious that medical education is difficult and valuable. For this reason, it is a gain for patients that doctors practice their professions that they work hard for. Assigning doctors to management positions can turn this gain into a loss and stress doctors.

Keywords: Hybrid Management, Hybrid Business Identity, Healthcare Management, Health.

Introduction

Since both people and bureaucracy are present together in obtaining our most precious treasure, health, the structure is quite chaotic. It does not seem easy to manage a chaotic structure. As a result, many branches of business in health institutions function inseparably. There is no other service sector that can replace health institutions. Therefore, health services are unique with their unique structure.

Below; management, health management, manager physician-nurse and hybrid management concepts will be included.

Management

It is the joint effort of more than one person organized around the same goal to plan, direct, organize and control the existing resources in a harmonious manner in order to use them efficiently and functionally (Arslan, 2020). Thus, in management activities where an organized effort is essential, effective allocation of resources is crucial to ensure service flow.

Health Management

Health management is the process of planning, organizing and then controlling the human and other medical resources in a coordinated manner in order to provide patients with all health activities, from the smallest health service imaginable to the most complex and technical health service (Hayran, 2018). The first health management education in Turkey was established with the opening of the School of Health Administration in 1963 (Çınaroğlu, 2012).

Physician and Nurse in Healthcare Management Position

The management of health institutions is mainly carried out by physicians. On the other hand, head nurses are assigned as Health Care Services Managers in hospitals. With the Decree Law No. 663 published in 2011, the Public Hospitals Association was established and the structure of hospital administration was changed. It was aimed to increase the employment of health management graduates in managerial positions (Bostan & Ağaç, 2019). However, this structure was short-lived. The dominance of managerial physicians continued. Although their positions progressed in this way, physicians frequently encountered lack of knowledge in the field of management, regarding the operation, legislation and official correspondence (Baynal Doğan, Demirtaş & Doğan, 2020).

When we look at Turkey's health management policies, we see that managers who are medical school graduates and have the title of *"physician"* are appointed to the management of institutions and organizations in the sectoral structure of health. In addition, it has been read that the mentioned managerial physicians are working as managers without receiving education in sciences such as accounting and finance, labor law, business management and economics (Demir, Okan & Bostan, 2015). Nowadays, the concept of health management rather than the concept of business management is established in the management of hospitals, albeit late, because the health sector is private and too important to be replaced by the services of another sector. Therefore, the accounting and financing of health services are also complex (Altıntop vd, 2022). Bu bağlamda hastane yöneticilerinin stratejik maliyet, muhasebe ve finansman, etkin kaynak tahsisi ve verimli planlama gibi alanlara dair bilgi ve tecrübeli olmaları önerilmektedir (Elden Ürgüp, 2022).

In the readings, it is seen that some doctors look favorably on management, while others accept it as forced. This situation strengthens the possibility of doctors who continue to be involuntary managers experiencing administrative pressure. On the other hand, the success of doctors who

cannot practice their profession involuntarily may decrease and this situation may have negative effects on patients (Kaya & Kaya, 2019).

Hybrid Management

According to the definition of the *Turkish Language Association*, hybrid is expressed as *"mixed"*. It is also used in the sense of *"merger"* and *"difference of origin"*. When viewed from a business perspective, it can be briefly defined as *"different/changed working styles"* (Baycan & Ata, 2012).

Hybrid management, is the act of management carried out by individuals who are managers outside of their main job. It is possible to encounter hybrid managers especially in important public positions such as military, university and health institutions. In fact, hybrid managers are so caught up in the task of managing that they have drifted far away from their real professions. Therefore, hybrid management activity can cause ambiguity in their job identities (Yeşilyurt, 2021). Hybrid management in businesses is a work identity dilemma between those who are brought into management and those who are professionalized in management. Hybrid managers often mediate between other employees and top management (Byrkjeflot & Kragh Jespersen, 2014).

It is a fact that hybrid managers who do not practice their profession in the field they studied but work in the management cadre have insufficient knowledge of specific management disciplines. On the other hand, there is income inequality in the salary payments of doctors and managers with other professional backgrounds. However, doctors are at a disadvantage in terms of knowledge and equipment regarding management science (Baynal Doğan, Demirtaş & Doğan, 2020).

In hybrid management, it is possible to evaluate managers in the categories of *"accidental hybrid manager"* and *"willing hybrid manager"*. Individuals who accidentally sit in management positions continue to be committed to their main job and do not lose their professional professionalism. On the other hand, individuals in the position of willing managers have developed a reflex of detachment from their main job and cooling down. Thus, hybrid managers who do not mind experiencing professional atrophy are eager to do the tasks assigned by senior management (Gerry McGivern et al., 2015).

Since the functioning of health institutions is not like other service sectors, *"professionalism"* is always a requirement. After all, the person who demands and receives the service is the person. The value of the phenomenon of health cannot be compared to any other phenomenon. In this sense, health institutions should be managed by specialized human capital who have real management skills. Professional managers are essential for the proper distribution of limited resources, prevention of waste and flawless execution of performance measurements (Çınaroğlu, 2012). Having a good command of current governance issues and modern management skills is also an extremely important need for nurses (Çiftçioğlu & Tunç, 2022). In addition, communication and coordination within and between institutions are important and necessary for healthcare businesses today (Akdaş et al., 2008). Healthcare managers who are part of the team must communicate well with other employees. Because no one can say that management activities are not affected by communication (Özkan & Kalender, 2020).

Hybrid management does not only threaten the functioning of health institutions. Because the failure to keep health expenditures under control has the potential to harm the country's economy due to financial performance losses and financial failure possibilities. In this direction, the first step in taking the necessary precautions will be to employ health managers who are trained from the core. It is thought that employees who are competent in the health management

curriculum, know the operating procedures and are compatible with the ability to manage business identities will be the solution by eliminating hybridization (Baynal Doğan, Demirtaş & Doğan, 2020). A good solution would be to replace the informal manager identities of medical-based managers with formal manager identities that are not medical-based (Akdaş et al., 2008).

When the literature is read, it is seen that doctors are not very close to management science and even have a desire to *"work independently"* due to their highly perceived professional identity. Because doctors are the main heroes of the health sector. They always reflect a prestigious business identity in a popular position. Therefore, since hospital management is a team work, it is also a kind of threat to physician autonomy (Çınaroğlu, 2012). On the other hand, there are also studies that show that physicians should be supported to become managers. It has been stated that physician participation will increase hospital performance (Özkan & Kalender, 2020).

Materials and Methods

Due to the lack of sufficient studies on hybrid management in health management and the gap in the literature, this review paper was attempted to be written. In order to benefit the readers, information on the subject was compiled and solution suggestions were made.

Findings and Discussion

In a study, it was determined that manager nurses experienced problems originating from legislation and senior management. When examined in detail, it was understood that they considered it a big problem to have to get approval from senior managers while making decisions while managing. It was also seen that they wanted the head nurse position to be independent (Öztürk, Yılmaz & Demir, 2010). However, health services are a sharing between departments. On the other hand, the professionalism of nursing is specific to the nursing profession. There is no such thing as a large decision-making mechanism such as managing the entire hospital. Therefore, nurses, who must be free in their professional practice, must recognize the authority of upper management and other health professional groups in actions that exceed their education (Vatan et al., 2012).

In gender-focused studies, it has been stated that there is no problem with female physicians becoming managers. The interesting thing is that female physicians who make this statement do not want to be managers. They stated that physicians other than themselves are suitable for managers (Limon & Paçacı, 2022).

In the study of Akdaş et al. (2008); it was read that individuals in the position of managerial physician wanted to continue this job. However, the majority of the participants stated that it was necessary to receive training in management science (Akdaş et al., 2008).

If a concise general conclusion is to be made;

- Employment problems of the "*Health Management Department"*
- The weakening of the physician's ability to practice the art of medicine
- The weakening of the nurse's care giving practices
- Patients not being able to benefit from successful physicians/nurses
- The responsibility and stress of managing a hospital
- Decrease in institutional performance

- Interruption of physicians' professional advancement
- Lack of knowledge about health management science threatens the functioning of healthcare institutions
- Deterioration of managerial decision-making mechanisms in healthcare institutions

Conclusion and Recommendations

The goal in contemporary business management is to have institutions managed by professionals and to keep up with the times (Çınaroğlu, 2012). On the other hand, it is seen that clinical efforts turn into bureaucratic efforts in managerial physicians or nurses. In other words, there is a shift from their main profession to the role of health care workers to the role of health care managers. Of course, this situation negatively affects the physician's ability. For example, it is a loss for patients if a surgeon who will perform successful surgeries is involved in the hospital's purchasing and sales. On the other hand, it can also damage the physician's professional success. Therefore, the possibility of professional isolation harming public health is a significant problem.

- In order to provide the desired level of efficiency and quality in health service delivery, health institutions should be managed by professionals who have received training in this field.
- In order for competent people to contribute to the institution, appointments should be made by taking into account education, merit, work experience, expertise and justice.
- Elective management courses can be added to the medical curriculum.
- There is a lack of literature in Turkey on hybrid management in healthcare. This issue should be taken into consideration in future studies (Kaya & Kaya, 2019).

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THE INNOVATIVE FACE OF HEALTH IN THE AGE OF DIGITAL TRANSFORMATION

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ABSTRACT

In today's changing and developing world, all businesses are experiencing a digital transformation and revolutionary innovations. A rapid and systematic revolution is reflected in all institutions, thus healthcare services also get their share of this process. In order to diagnose and treat patients with increasing demand in the highest quality, least cost and most effective way, medical technologies and current developments must be utilized. The population is now aging all over the world, chronic diseases are increasing, healthcare costs and expenses are increasing and people's expectations of a healthy life are at high levels. At this point, preventive healthcare services strengthened with an innovative perspective should be provided thanks to the government's strategic planning in order to prevent disease at their source before they occur.

The integration of modern medicine with technology positively affects treatment methods. Medical technologies such as tele-medicine, artificial intelligence applications, robotic microsurgeries, wearable health technologies, online health services, digital health data management and new drug development are reflections of innovation in health. Thus, modern health services can be provided to patients. Now, the patient profile has also changed and a "questioning patient" transformation is taking place. Therefore, health institutions that aim not to fall behind the times and can make innovative decisions and approach the patient holistically will be one step ahead of their competitors.

Digitalization in healthcare facilitates patient follow up by keeping data flow dynamic. Paperless hospital applications brought by digitalization prevent waste and eliminate unnecessary paperwork. As a result, diagnostic and treatment services that capture the new and the good will undoubtedly increase patient satisfaction and contribute to the development of health.

Keywords: Digital Transformation, Innovation in Healthcare, Healthcare Organizations, Research Development.

Introduction

The transformation of humanity from an agricultural society to an industrial society, and from an industrial society to an information society, has occurred with the traces of the past developing and being carried to the present day. The dizzying effects of the internet age are reflected in new lifestyles. A lifestyle isolated from technology cannot be considered, because technology is rapidly progressing and permeating every moment of our lives. Today, as in every sector, the reflections of digital transformation are seen in health. Mobile health applications, the internet of things (IoT), artificial intelligence (AI), cloud computing, Tele-Medicine, digital hospital, electronic health data, robotic operations and wearable health technologies are on the agenda (Yalman & Filiz, 2022).

Health Information Systems

Health information systems; carry the hospital forward in many areas such as effective time management, creating the right treatment program for the right diagnosis, working hours and workforce planning, continuous patient monitoring, efficient decision-making mechanism, ensuring data security, human resources management, combating rival businesses and functional archive systems. In terms of the patient, it provides fast response, electronic monitoring and quality advantages (Peker, Van Giersbergen & Biçersoy, 2018). Electronic health data is an ideal resource for saving time and money (Avaner & Fedai, 2017).

Since health information is in a wide range, cloud computing technology and electronic health databases offer advantages to hospitals. Information chain, health communication, quality and evidence-based medical procedures are carried out through hospital information systems. All data of the health sector is included in big data (Bozbuğa, Kurtulmuş Kosif & Öncül, 2021).

Innovation and Health

Innovation, in its simplest definition, is an act of production that is *"worth spending money on"* It is the creation of goods and services from a new idea (Aslan, 2019).

Innovation is a process and depends on the contact of many institutions with each other. It calls for interaction, not isolation. Elements such as information and work sharing between institutions, state contribution, and the development of the national innovation infrastructure are like a link in a chain (Mete, Boz, & Aslan, 2019).

In innovation steps that are based on innovation while improving invention, idea or service production activities, renewed formations are marketed to the customer. When its placement in healthcare is considered; patient files are archived in the hospital information system and a fast and effective data pool is created. Thus, all parameters that need to be known about the patient are presented to the healthcare personnel without wasting time and the treatment process progresses quickly. As a result, patient satisfaction and recovery levels increase (Serbest, 2024).

Innovation is a requirement of many institutions in the sectoral market, but it is also popular in healthcare institutions. Because the customer of the healthcare sector is the patient who flows continuously. Therefore, the healthcare sector should progress and develop day by day in order to meet patient expectations. Healthcare workers should be equipped with an innovative perspective (Avcı, 2017). The effects of innovation on quality in healthcare services should not be ignored. Because the innovative healthcare understanding of healthcare institutions that want to differentiate themselves from their competitors is the driving force of continuous quality development. Leaders who care about quality also care about innovation (Kurt, 2020).

Despite contemporary IT advances, the integration of innovative approaches into institutions is not at the expected level. Employees' participation, interest and talent are reflected in the process of accepting and implementing innovation. New applications that are essentially avoided may become more complex in the future. Therefore, the process should be facilitated with timely user adaptation. Although it is difficult to embrace innovation without resisting change, it will have a positive impact on health outcomes in the long term (Serbest, 2024).

The development of renewal activities specifically for health institutions and their importance by policy makers can provide vitality to the country's economy. Because the share of health services among institutions is quite high. In addition, innovation is a basic need in the modernized medical sector. Because the network society requires it. Therefore, states should pay attention to the importance of technology and innovative solutions in order to permanently improve human health (Memişoğlu & Kalkan, 2016). On the other hand, health literacy should be increased on an individual and community basis with realistic solutions in order to illuminate the innovative face of health (Orhan, 2022).

Investing in innovative changes in health is certainly a short-term goal. However, this investment is actually a gain in controlling future health expenditures. Because the effects of innovation will spread over a long period of time and the money spent at the beginning will become a kind of insurance for public health. Therefore, governments should be generous when spending on health innovation (Kamer & Sancar O, 2022). Due to the invaluable nature of human life and the criticality of disease tables, institutional risk analyses should always be reviewed when evaluating the innovative dimension of health (Aksay & Orhan, 2013).

Digitalization of Health

Digital Transformation in Healthcare; it refers to the comprehensive integration of digital technologies, data analytics and innovative processes into services to improve the delivery of healthcare services. The digitalization of health invites institutions in both the public and private sectors to become active. The digital integration phase requires mandatory participation so that there is no business that cannot move one step ahead of its current position (Avaner & Fedai, 2017). Digital changes in healthcare are making virtualization ordinary. Innovations that would have been unthinkable years ago are captivating people today. Even if they do not aspire to use them, the conditions brought by the age somehow cause them to cross paths with these innovations. In virtualization in healthcare, there is a remote service provision such as virtual medicine and virtual nursing (Akalın & Veranyurt, 2020).

Digitalization provides the following; (Samancı, 2024).

- Personalized Patient Care
- Health Equity and Increased Access
- Increased Productivity
- Cost-Effectiveness

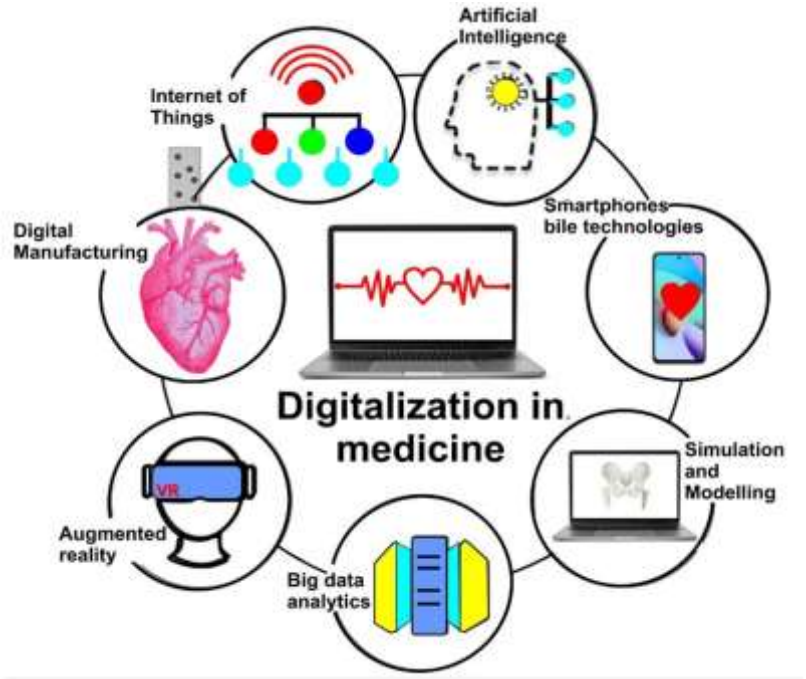


Figure 1. Digitalisation in medicine (Popov et al., 2022:).

Health 4.0

In the Health 4.0 structure, under the influence of Industry 4.0; hats that can measure body temperature and cardiac rhythms, robotic microsurgeries, smart prosthetic limbs, palm sensor reading systems, groundbreaking developments in heart and kidney treatments are emerging (Çalık et al., 2021).

In the research of Çalık et al.; Health 4.0 has been characterized as a sectoral innovation process, error-free new health, early diagnosis assistant, remote follower, individual-based applications. If we need to mention sample systems; specific applications such as *"DICOM, HES, MKYS, E-NABIZ, MHRS, ÜTS, HSYS, HBYS, EBYS"* can be listed in Turkish. Health 4.0, which is the basis of many applications, provides advantages in terms of quality and efficiency as well as disadvantages. There are negativities such as the possibility of not providing secure data management, insufficient informatics for Health 4.0, low health literacy, and lack of preparation in terms of law and economy (Çalık et al., 2021).

Health 4.0, which goes hand in hand with innovation, needs the support of the Ministry of Health in its current journey. Indeed, even though we are in the internet age, Turkey's infrastructure and medical information technology are still not fully prepared to carry out digital innovations. Therefore, collaborative, effective and smart strategies should be developed at the ministry level with ethical sensitivity. Only with these improvements can targeted original patient care and easy access to medicine be provided (Çelik & Okyay, 2023).

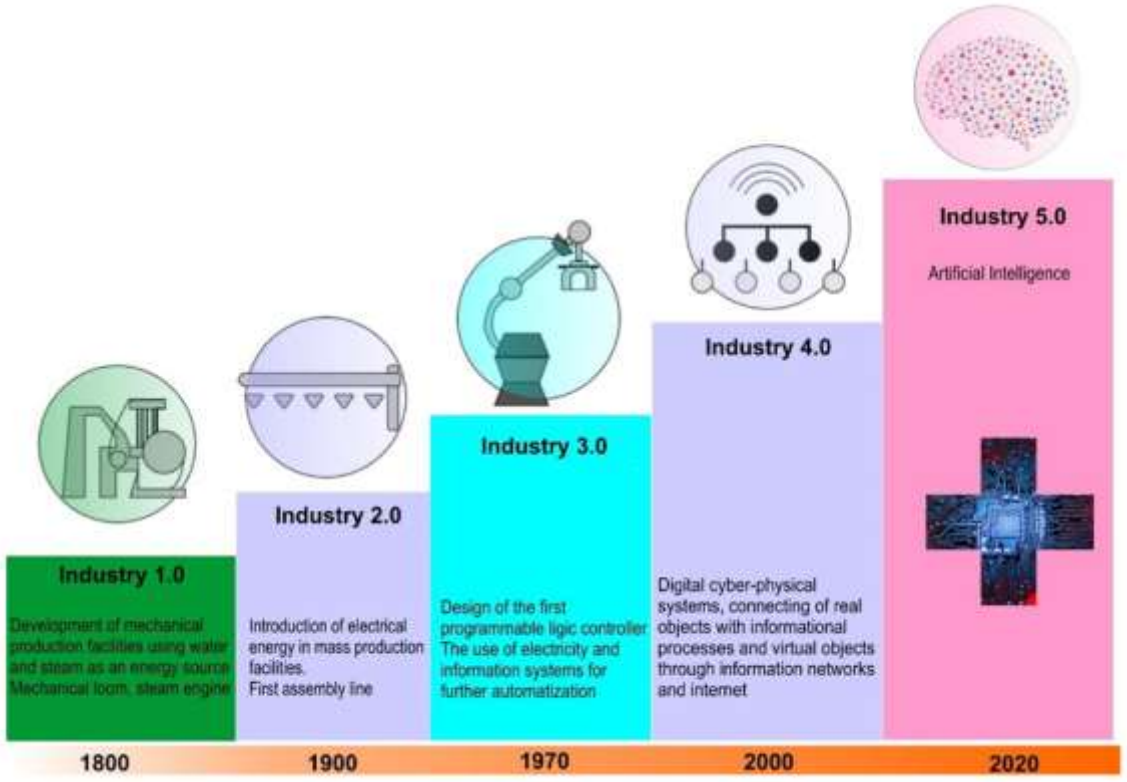


Figure 2. Evolution of industrial developments over time (Popov et al., 2022).

Benefits of Digital Transformation in Healthcare

Digitalization offers benefits in terms of providing effective and qualified services to individuals whose access to health is affected by geographical possibilities. In terms of sustainable health service provision, the greatest example was witnessed in the Covid-19 outbreak. During isolation periods, patients were followed up online and remotely, and an uninterrupted health supply was provided. Innovative approaches that serve human health in possible crises should always be supported by policy makers. Because it is known that these innovations contribute to positive health outcomes. For example, artificial intelligence can guide the physician by eliminating human error and producing flawless or nearly flawless results in disease diagnosis. Thus, even tiny lesions that may be overlooked by the physician are taken into consideration (Samancı, 2024).

Service providers offer fast, accessible, sustainable and improvable services to service recipients through digital health technologies. The reward of this synergistic effort is human health. The provision of up-to-date health-focused services in a digital framework also relieves the workload of healthcare professionals. Indeed, conducting transactions electronically saves healthcare professionals from struggling with paperwork and contributes to an increase in patient care time. Of course, in order to achieve these results, the development of our country's technical infrastructure, the elimination of cybersecurity barriers and the orientation of users to the operation are necessary (Samancı, 2024).

With medical technology opportunities, the perception of long distance is eliminated and patient observation is effectively provided by reaching the professional physician wherever he is (Kamer & Sancar O, 2022). Wearable medical technology designs provide self-control and data

flow to the physician (Akalın & Veranyurt, 2020). With the contributions of innovation in health, patient-based, original and functional treatment programs are obtained. With the leap forward in the medical industry, the examination of internal organs by sensor-based diagnostic tablets is an example of this. In addition, artificial organ designs with 3D printing technique are within the scope of digital service (Popov et al., 2022). Digital management of health data sets can reduce malpractice. More patients can be cared for with artificial intelligence-based medical systems. Big data can be controlled. (Bozbuğa, Kurtulmuş Kosif & Öncül, 2021).

Digital Hospital

The digitalization adventure in health has brought about digitalized health institutions, which are called *"digital hospitals"*. While the entire data system is electronic, patient follow-up is carried out over the network. Therefore, paperwork, filing and physical archiving processes will become history. Preventing paper waste also coincides with the theme of an environmentally friendly and green hospital. After all, resources are not unlimited. Paper waste is a serious problem in all public and private institutions and organizations. When we come to the main topic; digital hospitals are institutions that keep up with the times by using all the possibilities of the internet along with the development of medical technology (Ak, 2013).

Tele-Medicine: Telemedicine is the remote management of healthcare services with video, audio and data streaming components (Bozbuğa, Kurtulmuş Kosif & Öncül, 2021).

E-Health: Within the scope of the "Health Transformation Program", which was a resounding reform in Turkey in the 2000s, the "National Health Information System" infrastructure was established at the national level. It is a nationwide health data bank that is accessible to every citizen. On the other hand, this system stores the financial records, human resources and performance data of all health institutions (https://e-saglik.gov.tr/TR,6212/sagliknet-hakkinda.html).

E-Pulse: It is a system that allows patients to access all their health data via the network. It is an individual database where medical history is stored. All information for diagnosis and treatment planning can be accessed by relevant physicians through the system. Therefore, E-Pulse strengthens physician and patient communication (https://enabiz.gov.tr/Yardim/Index).

Materials and Methods

Since this study is a review, it is aimed to bring the information obtained by using the literature to the reader. It is aimed to create awareness about the digitalization in health and the renewed face of health, which has been the favorite subject of recent years. Therefore, accessible resources were scanned and an attempt was made to write content about the essence of the subject.

Findings and Discussion

The scenario expected to be encountered in the coming years can be expressed as follows; structurally reduced health institutions, online patient visits, continuous health monitoring with smart and wearable equipment, and more technological remote health applications. Of course, when it comes to human health, it is also possible that this distance and digitalization will create anxiety. Because the relationship between the health professional and the patient, who establish one-on-one contact for examination, will undergo a complete change (Aydamak, 2023). The status of service satisfaction is wondered due to physical conditions.

Reflections of Innovation in Healthcare ((Akalın & Veranyurt, 2020; Popov et al., 2022; Yalman & Filiz, 2022).

- Telemedicine / m-Health
- Artificial Intelligence (AI) applications
- Robotic microsurgeries
- 3D printing technology
- Wearable health technologies (VR, smartwatch, etc.)
- Online health services
- Digital health data management
- -e health records
- New drug development
- Elimination of manual processing losses (Time, labor and cost)
- Competitive advantage
- Paperlessness
- Cyber security and threat analysis
- Dynamic clinical decision system
- Contemporary processes
- Increased satisfaction
- Health 4.0

Conclusion and Recommendations

The use of digital technologies in the health sector for the purpose of improving and sustaining public health by prioritizing patient satisfaction refers to the digitalization of health. Digitalization also shapes health management policies and the most important policy is to reduce health expenditures (Stoumpos et al., 2023).

The increase in the patient population, or rather the aging of the world population, may make it difficult for hospitals to accept patients due to their physical inadequacies. In this sense, mobile health applications allow patient follow-up without the need for a physical environment. Thus, the occupancy rate of hospitals can be controlled (Bozbuğa, Kurtulmuş Kosif & Öncül, 2021). Digital transformation in health can provide convenience to physicians and reduce the number of patients' re-applications to health institutions. (Solmaz, Doğan Merih & Arga, 2020).

Orhan (2022) compares hospitals to an orchestra in his article. According to him, the result that emerges when all departments work in coordination and harmony is a perfect piece of music. In fact, this comparison is very logical since medicine is also an art. Doctors who perform their profession as artists save lives by working with zero error. It would not be wrong to say that there is no work more valuable than this. Therefore, diagnostic and treatment services that capture the new and the good will undoubtedly increase patient satisfaction and contribute to health outcomes.

Although our country's medical technology level is lower than that of the world's leading health countries, this is not an insurmountable problem. In this direction, our goal should be to produce technology instead of using it. Industrial enterprises, university research centers and the public sector should cooperate to produce technology so that this is a concrete effort. In short, we should produce instead of consuming (Şengün, 2016).

Recommendations;

- Strengthening cybersecurity to reduce the risk of data breaches for hospitals and healthcare facilities
- Creating an organizational structure that encourages collaboration and does not resist change
- Keeping patient expectations at the forefront

Thanks and Information Note

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(p, q) −MERSENNE QUATERNIONS AND THEIR BASIC PROPERTIES

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Abstract

In this study, we introduce a new generalization of classical Mersenne numbers by extending them into the quaternionic domain. We define the concept of Mersenne quaternions, which are built upon the traditional Mersenne number sequence and expanded using the algebraic rules of quaternions. Starting from the recursive definition of Mersenne numbers, we establish a second-order non-homogeneous recurrence relation for the corresponding quaternion sequence and derive its characteristic equation. Using this foundation, we then present the Binet formula for Mersenne quaternions, providing an explicit closed-form representation.

Furthermore, we construct both the ordinary generating function and the exponential generating function for Mersenne quaternions. These functions play a central role in analyzing the sequence's growth behavior and algebraic properties, while also serving as a bridge to deeper theoretical insights. The derivation of these formulas follows a systematic approach, employing initial conditions and known identities from classical sequence theory.

Although this study primarily focuses on the definition and core properties of Mersenne quaternions, it lays the groundwork for further exploration. In the continuation of this work, we aim to investigate Catalan, Cassini, and d'Ocagne identities in the quaternionic setting, as well as explore their potential applications in number theory and algebra. The results herein demonstrate that the rich structure of classical integer sequences can be successfully extended into higher-dimensional algebraic systems.

Keywords: Mersenne numbers, Mersenne quaternions, Binet formula, generating function, exponential generating function, recurrence relation, hypercomplex numbers.

1. Introduction

Classical integer sequences have long played a foundational role in number theory and algebra, offering deep insights through their recursive structures, generating functions, and closed-form expressions. Among these, Mersenne numbers—defined as numbers of the form $M_n = 2^n - 1$ hold a prominent place due to their rich arithmetic properties and connections to prime numbers, perfect numbers, and cryptographic algorithms. As mathematical inquiry continues to push the boundaries of classical frameworks, one natural direction of extension lies in the exploration of higher-dimensional algebraic structures such as quaternions.

In this study, we present a novel generalization of Mersenne numbers into the quaternionic domain by introducing the concept of *Mersenne quaternions*. Building upon the recursive formulation of classical Mersenne numbers, we define a corresponding second-order non-homogeneous recurrence relation for the quaternion sequence and derive its characteristic equation. This foundational step allows us to develop an explicit Binet-type formula for Mersenne quaternions, providing a closed-form representation that reveals the underlying structure of the sequence.

In addition, we construct both the ordinary and exponential generating functions associated with the sequence. These tools not only offer valuable algebraic representations but also shed light on the growth behavior and theoretical significance of Mersenne quaternions. By systematically deriving these results through established techniques in sequence analysis and quaternion algebra, this work bridges classical number theory with non-commutative algebraic systems.

While the primary aim of this paper is to define and explore the fundamental properties of Mersenne quaternions, our findings set the stage for further investigations. Potential extensions include examining quaternionic analogues of well-known identities such as those of Catalan, Cassini, and d'Ocagne, as well as exploring applications in abstract algebra and computational number theory. This study thus contributes to the broader effort of extending classical mathematical constructs into richer algebraic environments, highlighting both the versatility and depth of modern mathematical generalizations.

Among the most prominent integer sequences in mathematics, the Fibonacci sequence holds a central place due to its wide-ranging applications and rich structural properties. Scholars such as Hoggart and Koshy have contributed extensively to its study, and numerous researchers have explored polynomial extensions of such integer sequences as well (Koshy, 2001). A notable generalization of the Fibonacci sequence was introduced by Horadam (Horadam, 1963), whose formulation paved the way for further developments. In a more recent contribution, Yazlik and Taskara (Yazlık et al, 2012) proposed a broader generalization denoted by $\{H_{k,n}\}$, encompassing several classical second-order sequences, including Fibonacci, Lucas, k-Fibonacci, k-Lucas, generalized k-Fibonacci and k-Lucas, Horadam, Pell, Jacobsthal, and Jacobsthal-Lucas numbers.

Another noteworthy class of integer sequence is the Fermat numbers, first introduced in the 17th century by the French mathematician Pierre de Fermat. Defined by $F_n = 2^n + 1$, these numbers were named posthumously and have attracted significant mathematical interest. Tsang et al. have conducted detailed studies on Fermat numbers (Tsang et al., 2010, Boussayoud et al., 2018), and the potential relationships between Fermat and Fibonacci numbers have also been explored in the literature (Tsang et al., 2010, Abd-Elhameed et al., 2016, Robinson, 1954). Around the same period, Marin Mersenne, another French mathematician, introduced the sequence known as Mersenne numbers, defined by $M_n = 2^n - 1$. These numbers have been

the subject of extensive research across various mathematical domains, particularly number theory and combinatorics (Eser et al., 2023, Suvarnamani et al., 2015, Dişkaya et al., 2022, Aydin, 2018, Luna et al., 2012).

2. (p, q) −Mersenne Quaternions

Definition 1. (p, q) −Mersenne numbers are defined as follows,

$$M_{n+2}(p,q) = 3pM_{n+1}(p,q) - 2qM_n(p,q) \quad (1)$$

$n \geq 2$, with initial conditions $M_0(p,q) = 0, M_1(p,q) = 1,$

where p and q are nonzero real numbers such that $9p^2 - 8q > 0$.

Taking $p = 1, q = 1$ we obtain Mersenne numbers.

$M_2(p,q) = 3p,$

$M_3(p,q) = 9p^2 - 2q,$

$M_4(p,q) = 27p^3 - 12q,$

$M_5(p,q) = 81p^4 - 54p^2q + 4q^2$

The characteristic equation of (1) and its roots are given as follows,

$$\varphi(p,q) = \frac{3p - \sqrt{9p^2 - 8q}}{2} \quad , \qquad \phi(p,q) = \frac{3p + \sqrt{9p^2 - 8q}}{2}$$

One can easily see that

$$\varphi(p,q).\phi(p,q) = 2q$$

Binet formula of (p, q) −Mersenne numbers holds the following relation,

$$M_n(p,q) = \frac{\varphi^n(p,q) - \phi^n(p,q)}{\sqrt{9p^2 - 8q}} \quad (2)$$

where

$$\varphi(p,q) = \frac{3p - \sqrt{9p^2 - 8q}}{2} \quad , \qquad \phi(p,q) = \frac{3p + \sqrt{9p^2 - 8q}}{2}$$

Quaternions are among the most studied in algebra. In 1843, Hamilton [20] first introduced quaternions that extended complex numbers. These numbers are defined as follows,

$$H = \{1h_0 + e_1h_1 + e_2h_2 + e_3h_3 : h_0, h_1, h_2, h_3 \in \mathbb{R}\}$$

where $\mathbb{R}$ is the set of real number set and e_1, e_2, e_3 satisfies following equations.

$e_1{}^2 = e_2{}^2 = e_3{}^2 = -1,\ e_1e_2 = -e_2e_1 = e_3, e_2e_3 = -e_3e_2 = e_1, e_1e_3 = -e_3e_1 = e_2.$

Let us point out that quaternions are not commutative. Quaternions arise in quantum mechanics, physics, mathematics...etc.

Ipek [21] presented (p, q) − Fibonacci quaternions as follows,

$$QF_n(p,q) = F_n(p,q) + F_{n+1}(p,q)e_1 + F_{n+2}(p,q)e_2 + F_{n+3}(p,q)e_3$$

where $F_n(p,q)$ is the n-th $(p,q)-$ Fibonacci numbers and e_1, e_2, e_3 satisfies the rules in (22).

Definition 2. (p,q) −Mersenne quaternions are defined by

$$QM_n(p,q) = M_n(p,q) + M_{n+1}(p,q)e_1 + M_{n+2}(p,q)e_2 + M_{n+3}(p,q)e_3 \tag{3}$$

where $M_n(p,q)$ is the n-th $(p,q)-$ Mersenne numbers and e_1, e_2, e_3 satisfies the rules in (22). The recurrence relation of $(p,q)-$ Mersenne quaternions is given by

$$QM_{n+2}(p,q) = 3pQM_{n+1}(p,q) - 2qQM_n(p,q). \tag{4}$$

Therefore, the characteristic equation of (23) is

$$\sigma^2 - 3p\sigma + 2q = 0. \tag{5}$$

The roots of (24) are

$$\underline{\varphi}(p,q) = \sum_{s=0}^{3} \varphi^s(p,q)e_s = 1 + \varphi(p,q)e_1 + \varphi^2(p,q)e_2 + \varphi^3(p,q)e_3$$

$$\underline{\phi}(p,q) = \sum_{s=0}^{3} \phi^s(p,q)e_s = 1 + \phi(p,q)e_1 + \phi^2(p,q)e_2 + \phi^3(p,q)e_3.$$

Theorem 3. Binet formula of $(p,q)-$ Mersenne quaternions $\{QM_u\}$ is given by for $u \geq 0$,

$$QM_n = \frac{\underline{\varphi}(p,q)\varphi^n(p,q) - \underline{\phi}(p,q)\phi^n(p,q)}{\varphi(p,q) - \phi(p,q)} \tag{6}$$

Proof. By using (2), we have the following equation:

$$QM_n(p,q) = \sum_{s=0}^{3} M_{n+s}(p,q)e_s$$

$$QM_n = \frac{\underline{\varphi}(p,q)\varphi^n(p,q) - \underline{\phi}(p,q)\phi^n(p,q)}{\varphi(p,q) - \phi(p,q)} + \frac{\underline{\varphi}(p,q)\varphi^{n+1}(p,q) - \underline{\phi}(p,q)\phi^{n+1}(p,q)}{\varphi(p,q) - \phi(p,q)}e_1$$
$$+ \frac{\underline{\varphi}(p,q)\psi^{n+2}(p,q) - \underline{\phi}(p,q)\phi^{n+2}(p,q)}{\varphi(p,q) - \phi(p,q)}e_2$$
$$+ \left(\frac{\underline{\varphi}(p,q)\varphi^{n+3}(p,q) - \underline{\phi}(p,q)\phi^{n+3}(p,q)}{\varphi(p,q) - \phi(p,q)}\right)e_3.$$

Thus, the Binet formula of $(p,q)-$ Mersenne quaternions is obtained easily.

Here we present generating function, exponential generating function of (p,q) −Mersenne quaternions.

Theorem 4. The generating function of $(p,q)-$ Mersenne quaternions is defined by

$$G_{QM(p,q)}(t) = \frac{QM_0(p,q) + (QM_1(p,q) - 3pQM_0(p,q))t}{(1 - 3pt + 2qt^2)}$$

Proof.

$$G_{QM(p,q)}(t) = QM_0(p,q) + QM_1(p,q)t + QM_2(p,q)t^2 + \cdots + QM_m(p,q)t^m + \cdots$$

$$-3ptG_{QM}(t) = -3pBCQM_0t - 3pBCQM_1t^2 - 3pBCQM_2t^3 + \cdots + -3pBCQM_mt^{m+1} + \cdots$$

$$\begin{aligned} 2qt^2G_{QM(p,q)}(t) &= 2qQM_0(p,q)t^2 + 2qQM_1(p,q)t^3 + 2qQM_2(p,q)t^4 + \cdots \\ &+ 2qQM_m(p,q)t^{m+2} + \cdots \end{aligned}$$

Summation the both side of equations,

$$\begin{aligned} (1 - 3pt + 2qt^2)\, G_{QM}(p,q)(t) &= QM_0(p,q) + (QM_1(p,q) - 3pQM_0(p,q))t \\ &+ (QM_2(p,q) - 3pQM_1(p,q) + 2qQM_0(p,q))t^2 + \cdots \\ &+ (QM_m(p,q) - 3pQM_{m-1}(p,q) + 2qQM_{m-2}(p,q)) + \cdots \end{aligned}$$

Using (17) and initial conditions we get

$$(1 - 3pt + 2qt^2)G_{BM}(t) = QM_0(p,q) + (QM_1(p,q) - 3pQM_0(p,q))t$$

$$G_{QM(p,q)}(t) = \frac{QM_0(p,q) + (QM_1(p,q) - 3pQM_0(p,q))t}{1 - 3pt + 2qt^2}$$

Now we give exponential generating function of $\{QM_u(p,q)\}$ as follows,

Theorem 5. Exponential generating function of (p,q) − Mersenne quaternions is defined by

$$E_{QM(p,q)}(t) = \frac{\underline{\varphi}(p,q)e^{\varphi t} - \underline{\phi}(p,q)e^{\phi t}}{\varphi(p,q) - \phi(p,q)}$$

where

$$\acute{\varphi}(p,q) = 1 + \varphi(p,q)e_1 + \varphi^2(p,q)e_2 + \varphi^3(p,q)e_3$$

$$\acute{\phi}(p,q) = 1 + \phi(p,q)e_1 + \phi^2(p,q)e_2 + \phi^3(p,q)e_3.$$

Proof.

$$e^t = \sum_{t=0}^{\infty} \frac{t^u}{t!} \tag{6}$$

Using above equations, we get

$$EQM_n(p,q)(t) = \sum_{n=0}^{\infty} QM_n(p,q)\frac{t^n}{n!}$$

If we write Binet formula instead of $QM_n(p,q)$ and do some algebraic calculation, we get desired conclusion.

Theorem 6. (Catalan identity)

$$\begin{aligned} QM_{n-r}(p,q).QM_{n+r}(p,q) - (QM_n(p,q))^2 &= \\ \frac{2^{n+1}q^n\underline{\varphi}(p,q)\varphi^n(p,q)\left(1 - \underline{\varphi}^{-r}(p,q)\phi^r(p,q)\right)}{9p^2 - 8q} & \end{aligned}$$

Proof.

Using Binet formula for Mersenne quaternions at (6)

$$QM_{n-r}(p,q).QM_{n+r}(p,q) - (QM_n(p,q))^2$$
$$= \frac{2\underline{\varphi}(p,q)\underline{\phi}(p,q)(2q)^n(1-\varphi^{-r}(p,q))\phi^r(p,q)}{(\varphi(p,q)-\phi(p,q))^2}$$
$$= \frac{2^{n+1}q^n\underline{\varphi}(p,q)\varphi^n(p,q)\left(1-\underline{\varphi}^{-r}(p,q)\phi^r(p,q)\right)}{9p^2-8q}$$

Theorem 7. (Cassini identity)

$$QM_{n-1}(p,q).QM_{n+1}(p,q) - (QM_n(p,q))^2 = \frac{2^{n+1}q^n\underline{\varphi}(p,q)\varphi^n(p,q)\left(1-\frac{\phi(p,q)}{\varphi(p,q)}\right)}{9p^2-8q}$$

Proof. Taking $r = 1$ in Catalan identity we get the desired conclusion.

Theorem 8. (D'ocagne identity)

$$QM_n(p,q).QM_{m+1}(p,q) - QM_m(p,q).QM_{n+1}(p,q) = \frac{\underline{\varphi}(p,q)\underline{\phi}(p,q)(2q)^n(\phi^{m-n}(p,q)-\varphi^{m-n}(p,q))}{\varphi(p,q)-\phi(p,q}$$

Proof.

$$QM_n(p,q).QM_{m+1}(p,q) - QM_m(p,q).QM_{n+1}(p,q$$
$$= \frac{\underline{\varphi}(p,q)\underline{\phi}(p,q)\varphi^n(p,q)\phi^m(p,q)(\varphi(p,q)-\phi(p,q)) - \underline{\varphi}(p,q)\underline{\phi}(p,q)\varphi^m(p,q)\phi^n(p,q)(\varphi(p,q)-\phi(p,q))}{(\varphi(p,q)-\phi(p,q))^2}$$
$$= \frac{\underline{\varphi}(p,q)\underline{\phi}(p,q)(2q)^n(\phi^{m-n}(p,q)-\varphi^{m-n}(p,q))}{\varphi(p,q)-\phi(p,q)}$$

Theorem 9. (Honsberger identity)

$$QM_{m-1}(p,q).QM_n(p,q) - QM_m(p,q).QM_{n+1}(p,q)$$
$$= \frac{-\underline{\varphi}(p,q)\underline{\phi}(p,q)(\varphi^{m-1}(p,q)\phi^n(p,q)) + \underline{\varphi}^2(p,q)\varphi^{m+n}(p,q)\left(\underline{\varphi}^{-1}(p,q)+\varphi(p,q)\right) + \underline{\phi}^2(p,q)\phi^{m+n}(p,q)\left(\underline{\phi}^{-1}(p,q)+\phi(p,q)\right)}{9p^2-8q}$$

Proof.

$$\frac{\underline{\varphi}(p,q)\varphi^{m-1}(p,q)-\underline{\phi}(p,q)\phi^{m-1}(p,q)}{\varphi(p,q)-\phi(p,q)}.\frac{\underline{\varphi}(p,q)\varphi^n(p,q)-\underline{\phi}(p,q)\phi^n(p,q)}{\varphi(p,q)-\phi(p,q)}$$
$$+\frac{\underline{\varphi}(p,q)\varphi^m(p,q)-\underline{\phi}(p,q)\phi^m(p,q)}{\varphi(p,q)-\phi(p,q)}.\frac{\underline{\varphi}(p,q)\varphi^{n+1}(p,q)-\underline{\phi}(p,q)\phi^{n+1}(p,q)}{\varphi(p,q)-\phi(p,q)}$$

If we do some algebraic calculations, we get desired conclusion.

3. Conclusion

This work introduces Mersenne quaternions as a hypercomplex extension of classical Mersenne numbers. After defining the sequence and establishing its recurrence structure, we derived the characteristic equation and Binet formula. Additionally, both the ordinary and exponential

generating functions of Mersenne quaternions were obtained. These results reveal the structural richness of the quaternionic generalization and demonstrate that traditional methods in number theory can be extended into the quaternion domain. Future research will aim to deepen this framework by deriving analogs of known identities such as Catalan and Cassini, further expanding the theoretical landscape of special number sequences in hypercomplex settings.

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EVALUATING PMSM TECHNOLOGY WITHIN SUSTAINABLE TRANSPORTATION FRAMEWORKS: A CASE FOR ELECTRIC VEHICLES

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ABSTRACT

This study presents a comprehensive analysis of Permanent Magnet Synchronous Motors (PMSMs), which are widely employed in electric vehicles. Due to their high efficiency, compact structure, low maintenance requirements, and reliable operation, PMSMs hold a critical position within electric vehicle technology. The paper initially emphasizes the role of electric vehicles in achieving sustainable transportation goals, and subsequently examines in detail the structural characteristics, operational principles, advantages, and technical comparisons of PMSMs with other motor types. The analysis includes the two main variants of PMSMs—Surface-mounted PMSMs (SPMSM) and Interior PMSMs (IPMSM)—highlighting their respective torque production capabilities, efficiency levels, and resistance to demagnetization. The function of PMSMs within the electric drivetrain is elucidated through their contributions to acceleration, deceleration, and regenerative braking. Furthermore, the study evaluates the impact of PMSMs on key vehicle performance parameters, such as speed, torque, driving range, comfort, and safety. A comparative assessment with DC motors, induction motors, and switched reluctance motors (SRMs) is also provided, wherein PMSMs are demonstrated to outperform their counterparts particularly in terms of energy efficiency, noise reduction, and compact design. Additionally, their regenerative braking capability enables energy recovery, thereby extending battery lifespan and enhancing vehicle range. In conclusion, the study underscores PMSMs as the most suitable motor type for electric vehicles from both technical and environmental perspectives, reaffirming their critical role in advancing sustainable transportation solutions.

Keywords: Permanent Magnet Synchronous Motor (PMSM), Electric Vehicles, Sustainable Transportation, Energy Efficiency, Motor Performance Analysis

Introduction

Electric vehicles (EVs) have emerged in recent years as alternative modes of transportation developed to address critical global issues such as global warming, energy crises, air pollution, and the depletion of petroleum resources (Havale et al., 2025). EVs convert electrical energy—sourced from batteries or other electrical systems—into mechanical energy via electric motors, enabling vehicle propulsion (Rausa et al., 2025). The electric motors used in EVs significantly impact vehicle performance, efficiency, safety, and comfort (Kıyak & Kaya, 2020). Among the electric motor types employed in EVs, the Permanent Magnet Synchronous Motor (PMSM) is widely used (Yang et al., 2020). A PMSM is a synchronous motor that features permanent magnets on the rotor and is supplied with three-phase AC current in the stator. These motors offer numerous advantages, including high power density, high efficiency, low noise, reduced maintenance costs, wide speed range, and excellent controllability. PMSMs serve as the core components of the EV traction system, which converts electrical energy into mechanical energy to drive the vehicle. The traction system consists of the battery, charging unit, power electronics, electric motor, transmission, differential, and wheels. Within this system, the PMSM receives AC current from the power electronics and generates mechanical power that adjusts the vehicle's speed and torque (Sain et al., 2021).

This article provides a comprehensive overview of the PMSMs used in electric vehicles. The subsequent sections detail the structure, operating principles, advantages, and role of PMSMs within the traction system, as well as comparisons with other types of electric motors. Furthermore, the relationship between PMSMs and EV performance is analyzed. The final section emphasizes the critical role of PMSMs in modern electric vehicle technologies.

Electric Vehicles (EVs)

An electric vehicle is a type of transportation that converts electrical energy—supplied by a battery or other electrical sources—into mechanical energy through an electric motor to enable vehicle movement. During the design phase of electric vehicles, the generation and distribution of energy within the vehicle are managed by the components of the traction system (Kerem, 2014). Compared to internal combustion engine (ICE) vehicles, electric vehicles are more efficient, quieter, cleaner, and more economical (Ghodrati, 2024). Additionally, they can be categorized into various types, such as battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), series hybrid electric vehicles, parallel hybrid electric vehicles, series-parallel hybrid electric vehicles, fuel cell electric vehicles (FCEVs), and solar-powered electric vehicles. These vehicles typically share common components including an electric motor, battery, charging unit, power electronics, transmission, differential, and wheels. The selection, design, and control of these components play a crucial role in determining the vehicle's performance, efficiency, safety, and comfort.

Electric Vehicles and the Importance of Sustainable Transportation

Electric vehicles are a vital component of sustainable transportation. Sustainable mobility aims to provide economically efficient movement, foster local economic development, and ensure functional performance. From a social perspective, the objectives of sustainable transportation include ensuring human safety and health, promoting social equity, overcoming economic challenges, fostering social cohesion, and preserving cultural values. Environmentally, sustainable transportation seeks to reduce air, noise, and water pollution, conserve natural resources, protect open spaces, and maintain biodiversity (Alomare et al., 2025).

Sustainable transportation refers to a mode of transport that enables the movement of people and goods without causing harm to the environment, human health, or the economy. It has been

developed in response to critical issues such as global warming, energy crises, air pollution, and the depletion of petroleum resources. In the context of promoting sustainable transportation, electric vehicles offer the following advantages:

• Higher Efficiency: Compared to internal combustion engine (ICE) vehicles, EVs are significantly more efficient. While EVs convert approximately 80–90% of electrical energy into mechanical energy, ICE vehicles only convert 20–30% of the fuel's energy. This means EVs can travel longer distances with less energy consumption.

• Lower Emissions: EVs are cleaner than ICE vehicles. They emit no harmful gases through tailpipes, thereby contributing to reductions in air pollution, greenhouse gas emissions, and global warming (Sudjoko et al., 2021).

Permanent Magnet Synchronous Motors (PMSM)

PMSMs are a class of synchronous motors widely used in various applications. These motors are powered by three-phase alternating current (AC) in the stator and feature permanent magnets on the rotor. PMSMs operate based on synchronization between the magnetic field generated in the stator windings and the magnetic field of the rotor magnets. Additionally, since the rotor magnets directly produce the rotor's magnetic flux, these motors exhibit very high efficiency (Koçaş, 2023).

PMSMs can be categorized into the following subtypes:

• Surface-Mounted Permanent Magnet Synchronous Motor (SPMSM): In this type, the rotor magnets are mounted on the surface of the rotor. SPMSMs offer advantages such as high speed, high power density, and low torque ripple. However, they also have drawbacks including high cost, limited torque capability, and susceptibility to demagnetization.

• Interior Permanent Magnet Synchronous Motor (IPMSM): In this configuration, the rotor magnets are embedded within the rotor core. IPMSMs provide benefits such as lower cost, higher torque output, improved efficiency, and greater resistance to demagnetization. On the downside, they have a more complex structure, lower power density, and higher torque ripple.

The structural differences between SPMSM and IPMSM configurations are illustrated in Figure 1.

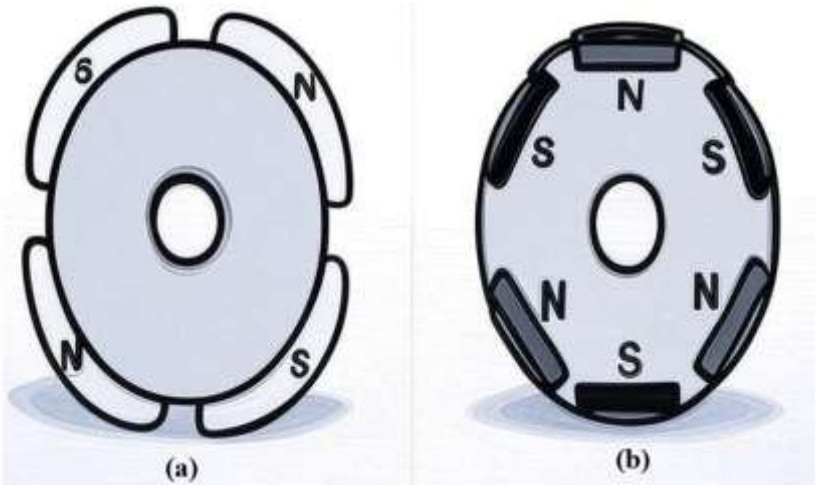


Figure 1. Surface-Mounted Permanent Magnet Synchronous Motor (a) and Interior Permanent Magnet Synchronous Motor (b) (Tören & Mollahasanoğlu, 2023)

Working Principle of PMSM

A Permanent Magnet Synchronous Motor is not fundamentally different from any other rotary electric motor in that it consists of a rotor and a stator. The stator is the stationary part, while the rotor is the rotating component. What distinguishes a PMSM from an asynchronous (induction) motor lies in the rotor structure, which includes permanent magnets. The PMSM can be considered a hybrid structure combining features of both induction motors and brushless DC motors. Like a brushless DC motor, it has a permanent magnet rotor and a wound stator. However, the stator windings are designed to produce a sinusoidal flux density in the air gap, similar to that of an induction motor's stator design. The general structure of a PMSM is illustrated in Figure 2.

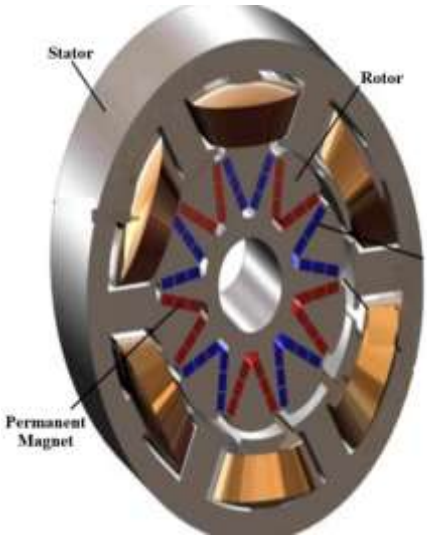


Figure 2. General Structure of PMSM (Zhao et al., 2022).

Regarding the operating principles of PMSM motors, the stator structure of a PMSM resembles that of an asynchronous motor, while the rotor contains permanent magnets that produce a constant magnetic field. These permanent magnets provide a lossless excitation without the need for an external electrical circuit. In asynchronous motors, a rotating magnetic field is generated by a three-phase symmetric AC supply to the stator windings. Since synchronous motors cannot start by themselves, PMSMs require an initial starting mechanism. As there are no windings on the rotor, induction-based starting methods are not suitable for such motors, which is why a variable-frequency power supply is required (Dursun et al., 2018).

When the magnetic field of the rotor interacts with the synchronous AC current applied to the stator windings, a torque is generated that causes the rotor to rotate. To maintain a constant average torque, the rotor must follow the stator's rotating field and spin at the same synchronous speed. During operation, the three-phase windings—similar to those in an asynchronous motor—are energized either with a trapezoidal current waveform (as in brushless DC motors) or a sinusoidal current waveform (as in synchronous AC motors). These currents generate a magnetic field that rotates at the same speed as the rotor, or at synchronous speed. By adjusting the frequency of the stator current, the rotor speed (i.e., synchronous speed) can be regulated accordingly (Meenakshi & Paramasivam, 2017).

Advantages of PMSM Motors

Permanent Magnet Synchronous Motors are widely used in many applications due to their numerous advantages, including high efficiency, high power density, simple structure, and

reliable operation (Singh et al., 2023). Compared to other types of electric motors, PMSMs offer the following benefits:

• High energy efficiency: Since PMSMs use permanent magnets on the rotor, there are no rotor-related energy losses. Additionally, the reduced amount of copper used in stator windings leads to lower copper losses. This means PMSMs can convert electrical energy into mechanical energy more efficiently.

• High power density: The permanent magnets in the rotor generate a strong magnetic flux density, enabling PMSMs to deliver higher power output in a more compact size.

• Low noise and vibration: Due to the synchronization between rotor magnets and stator windings, torque ripple and speed fluctuations are minimized. As a result, PMSMs operate more smoothly and quietly.

• Low maintenance cost and reliable operation: As PMSMs do not include brushes, commutators, belts, or gears—components prone to wear or failure—they require less maintenance and offer longer operational lifespans.

Role of PMSM Motors in the Traction System

PMSM motors serve as the primary component of the traction system in electric vehicles. The traction system is responsible for converting electrical energy into mechanical energy to drive the vehicle. It consists of the battery, charging unit, power electronics, electric motor, transmission, differential, and wheels. Within this system, the PMSM receives AC current supplied by the power electronics and produces mechanical power that regulates the vehicle's speed and torque (Huang et al., 2023).

PMSM motors perform the following functions within the traction system:

• Enable the acceleration, deceleration, and stopping of the vehicle.

• Allow the vehicle to adapt to various road conditions and driver demands.

• Improve the energy efficiency and driving range of the vehicle.

• Reduce the levels of noise, vibration, and emissions generated by the vehicle.

Comparison of PMSM Motors with Other Motor Types

PMSM motors can be compared to other types of electric motors commonly used in electric vehicles as follows:

• DC Motors: DC motors operate on direct current and include mechanical switching components such as brushes and commutators. They offer advantages such as simple control, high torque output, and a wide speed range. However, they suffer from drawbacks including brush and commutator wear, higher maintenance costs, noise, sparking, and electromagnetic interference. Compared to DC motors, PMSM motors are more efficient, more reliable, quieter, and have a longer operational lifespan (Gore & Ugale, 2022).

• Induction Motors: Induction motors are asynchronous machines powered by three-phase AC current in the stator and feature either squirrel-cage rotors or wound rotors with short-circuited windings. These motors are known for their simple construction, low cost, high reliability, and durability. Nevertheless, they have disadvantages such as lower power density, reduced efficiency, low power factor, higher losses, and more complex control requirements. PMSM motors, in comparison, offer better efficiency, a more compact structure, higher performance, and simpler control (Kıyak & Kaya, 2020).

The architectural comparison between an induction motor and a permanent magnet motor is illustrated in Figure 3.

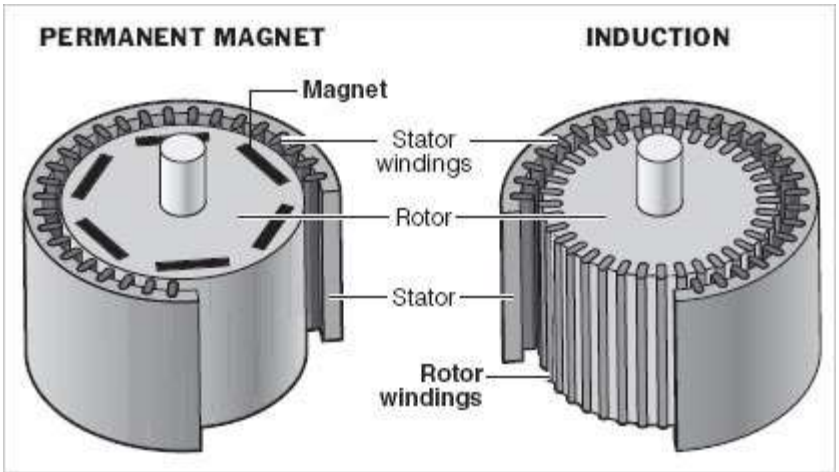


Figure 3. Structural comparison of a Permanent Magnet Synchronous Motor and an Induction Motor (New Energy and Fuel, 2010).

• Switched Reluctance Motors (SRMs): SRMs are synchronous motors powered by three-phase AC current in the stator, with no permanent magnets or windings on the rotor. These motors offer advantages such as simple structure, low cost, high-speed operation, high reliability, and strong resistance to demagnetization. However, they also present several disadvantages, including low power density, reduced efficiency, high noise levels, significant torque ripple, and complex control strategies. Compared to SRMs, PMSM motors are more efficient, quieter, smoother in operation, and easier to control. When comparing the torque characteristics of all motor types, it is evident that PMSMs exhibit less torque ripple due to the demagnetization effects in the air gap caused by the presence of permanent magnets. Torque ripple content directly influences the overall efficiency of the motor (Pandraka et al., 2024).

The Importance of PMSM Motors in Electric Vehicles and Their Relationship with Performance

PMSM motors are closely associated with the performance of electric vehicles. EV performance refers to various characteristics such as vehicle speed, torque, acceleration, deceleration, range, efficiency, safety, and comfort. PMSM motors influence electric vehicle performance in the following ways:

• Speed and Torque: Thanks to their high-power density and wide speed range, PMSM motors provide electric vehicles with high speed and torque capabilities. PMSMs allow precise control of speed and torque via power electronics and control systems.

• Acceleration and Deceleration: Due to their high torque capability and fast dynamic response, PMSM motors deliver excellent acceleration and deceleration characteristics. These functions are dynamically managed through power electronics and control systems. Additionally, PMSM motors support regenerative braking, which enables energy recovery. In regenerative braking, the motor operates as a generator during deceleration, converting mechanical energy into electrical energy and feeding it back into the battery.

• Range and Efficiency: PMSM motors provide high range and efficiency due to their high energy conversion efficiency and low energy losses. They convert electrical energy into

mechanical energy with minimal loss, reducing energy consumption from the battery. Through regenerative braking, additional energy can be recovered, which in turn extends battery life and reduces charging frequency.

• Safety and Comfort: With their low noise, low vibration, reduced heating, and low maintenance characteristics, PMSM motors contribute significantly to the safety and comfort of electric vehicles. These motors minimize noise, vibration, and thermal effects inside the vehicle, improving cabin conditions. Moreover, since they lack components prone to wear or failure—such as brushes, commutators, belts, and gears—they reduce the need for maintenance and the risk of mechanical failure (Rusli et al., 2023).

The importance of PMSM motors in electric vehicles is evident from the advantages described above. PMSMs provide high performance, high efficiency, high safety, and superior comfort. Additionally, they enhance the positive impact of electric vehicles on the environment, human health, and the economy. PMSM motors are fundamental in making electric vehicles a key component of sustainable transportation. They play a pivotal role in the development and widespread adoption of electric vehicle technology.

In EV systems, the electrical energy required by the PMSM-based drive system is supplied by the battery. In addition to controlling the battery modules and PMSM, there are also several external factors—such as the transmission, wheels, axles, and other dynamic cycle components—that influence the overall system stability, as illustrated in Figure 4. Therefore, the condition of both the PMSM and the onboard battery pack are of critical importance (Zhang et al., 2023).

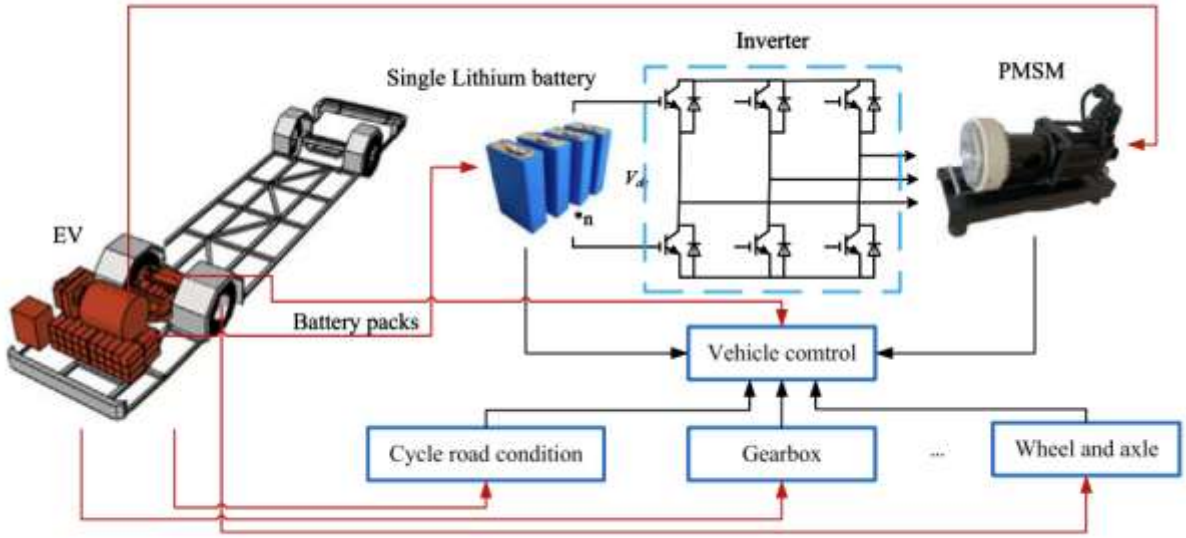


Figure 4. Schematic diagram of EV system (Zhang et al., 2023).

Conclusion

Electric vehicles are a crucial component of sustainable transportation. Compared to internal combustion engine (ICE) vehicles, EVs are more efficient, quieter, cleaner, and more economical. The electric motors used in EVs significantly influence vehicle performance, range, and reliability. This study focused on Permanent Magnet Synchronous Motors (PMSMs), which are among the most commonly used motor types in electric vehicles. A PMSM is a synchronous motor that operates using a magnetic field generated by permanent

magnets. PMSMs offer several advantages, including high efficiency, high power density, low noise, low maintenance, simple control, and a wide speed range. They serve as a critical component of the EV traction system. PMSMs provide high torque, rapid acceleration, regenerative braking capability, and high energy efficiency. When compared to other types of motors, PMSMs deliver superior performance in electric vehicle applications. This study examined the structure, operating principle, advantages, role in the traction system, and comparison of PMSMs with other motor types. Additionally, the relationship between PMSMs and electric vehicle performance was analyzed. In conclusion, the use of PMSMs in electric vehicles is found to be a highly suitable option for achieving the goals of sustainable transportation.

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MACHINE LEARNING-BASED ESTIMATION OF ACTIVE POWER IN WIND ENERGY SYSTEMS

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ABSTRACT

As the demand for renewable energy continues to rise, wind power has become one of the most prominent and widely adopted sources of sustainable electricity. Wind turbines, however, are complex systems influenced by numerous environmental and operational variables. Accurately forecasting their power output is essential for improving efficiency, optimizing maintenance strategies, and ensuring reliable integration into power grids. In this project, machine learning regression models were employed to predict the active power output of a wind turbine based on multidimensional sensor data. After pre-processing steps, including the removal of redundant features and imputation of missing values, three regression algorithms were developed and evaluated: Linear Regression, Random Forest Regressor, and Extra Trees Regressor. The models were trained on a selected set of input features encompassing environmental conditions and internal turbine metrics. Performance evaluation using the coefficient of determination (R^2) revealed a clear advantage for ensemble learning methods. Linear Regression yielded an R^2 score of 0.8978, while Random Forest and Extra Trees achieved significantly higher scores of 0.9962 and 0.9967, respectively. These results indicate that tree-based ensemble models are highly effective in capturing complex, nonlinear relationships within turbine data. The study demonstrates the potential of data-driven approaches in modelling wind turbine behavior and provides a foundation for intelligent decision-making in the field of renewable energy systems.

Keywords: Machine Learning, Renewable Energy Forecasting, Wind Turbine Power Prediction, Active Power Estimation

Introduction

The global imperative to transition towards sustainable energy systems has significantly amplified the role of renewable sources, with wind power emerging as a leading technology in this paradigm shift. Wind energy offers a substantial contribution to mitigating climate change and enhancing energy security, driven by its increasing technological maturity and economic competitiveness. At the heart of this technology are wind turbines, complex electromechanical systems designed to convert the kinetic energy of wind into electrical power. The performance of these turbines is intrinsically linked to a dynamic interplay of fluctuating environmental conditions and internal operational parameters. Consequently, the ability to accurately predict their active power output is of paramount importance. Such predictions are crucial not only for optimizing the operational efficiency of individual turbines and entire wind farms but also for ensuring their reliable integration into power grids, facilitating proactive maintenance strategies, and supporting informed decision-making in energy markets.

Despite its advantages, the inherent intermittency and variability of wind resources pose considerable challenges to the stable operation of power systems and the predictability of energy generation. To address these challenges, extensive research has been dedicated to developing sophisticated forecasting models. While traditional physics-based models provide foundational understanding, they often encounter limitations when dealing with the complex, non-linear dynamics characteristic of wind turbine operations and the diverse geographical and meteorological contexts in which they operate. In recent years, machine learning (ML) methodologies have gained significant traction as powerful alternatives, demonstrating a remarkable capacity to discern intricate patterns and relationships directly from historical operational data, thereby offering enhanced predictive accuracy.

The application of ML in the domain of wind energy is multifaceted, extending beyond simple power forecasting. Researchers have explored ML for comprehensive optimization of wind energy systems, including predictive maintenance through anomaly detection and the development of adaptive control systems to enhance energy capture based on real-time environmental and operational data (Udo et al., 2024). Such holistic approaches aim to reduce downtime and improve overall turbine performance significantly. For short-range wind power estimation specifically, ML has introduced novel techniques, including hybrid models that combine the strengths of different algorithms, such as generalized regression neural networks (GRNN) with optimization techniques like whale optimization, to improve forecasting accuracy and quantify uncertainty (Al-Samalek et al., 2024). These advancements are vital for the effective management of active power within wind energy systems.

Among the various ML paradigms, deep learning models, particularly those designed for sequential data, have shown considerable promise. Multilayer Long Short-Term Memory (LSTM) networks, for instance, have been effectively utilized for estimating active power by leveraging time-series data from SCADA (Supervisory Control and Data Acquisition) systems, adeptly capturing temporal dependencies and the influence of environmental factors (Çelebi & Karaman, 2023). A broader investigation into various neural network architectures—including Artificial Neural Networks (ANNs), Recurrent Neural Networks (RNNs), Convolutional Neural Networks (CNNs), in addition to LSTMs—has further confirmed the robustness of these approaches in wind power forecasting, with LSTMs often exhibiting superior performance due to their inherent ability to model long-term temporal relationships (Karaman, 2023). Comparative analyses of different ML techniques, such as feed-forward neural networks (often referred to as Backpropagation Neural Networks or BPNNs) and Support Vector Regression

(SVR), have also been conducted to evaluate their efficacy and provide a clearer understanding of their respective strengths and weaknesses in this application (Kannan, 2023).

Ensemble learning methods, which combine multiple learning algorithms to obtain better predictive performance, have also been a focal point of recent research. Advanced ML techniques including LightGBM, Random Forest (RF), CatBoost, and XGBoost have been evaluated for very-short-term wind power forecasting, demonstrating high accuracy crucial for real-time operational decisions and maintenance planning (Ponkumar et al., 2023). Furthermore, studies have specifically proposed and validated the use of models like Support Vector Regression (SVR) and Random Forest Regression (RFR) for forecasting wind energy production, highlighting the versatility and effectiveness of these established ML algorithms (Margarat et al., 2023).

Despite the considerable advancements in applying ML to wind power prediction, the optimal selection of input features, appropriate data preprocessing techniques, and the most suitable ML model architecture remain critical research questions that depend on specific dataset characteristics and application requirements. This study aims to contribute to this evolving field by conducting a systematic evaluation of three distinct regression models: Linear Regression, Random Forest Regressor, and Extra Trees Regressor. These models are applied to predict the active power output of a wind turbine using a multidimensional set of sensor data. Through rigorous data preprocessing, including handling missing values and removing redundant features, and by employing the coefficient of determination (R^2) for performance evaluation, this work seeks to elucidate the effectiveness of these models, particularly tree-based ensemble methods, in capturing the complex, non-linear relationships inherent in wind turbine operational data. The findings are intended to provide valuable insights for the development of intelligent, data-driven decision-making tools within the renewable energy sector.

Materials and Methods

This section details the methodology employed in this study to predict the active power output of a wind turbine using machine learning techniques. It encompasses a description of the dataset utilized, an overview of the data preprocessing steps undertaken, and a comprehensive explanation of the machine learning algorithms implemented and evaluated.

Dataset Description

The data utilized in this study was sourced from a publicly available dataset on the Kaggle platform, a well-known repository for data science projects and competitions. This dataset comprises time-series recordings of various operational and environmental parameters from a wind turbine. Such datasets, rich in sensor readings, are characteristic of those used in the monitoring and performance analysis of wind energy systems. While the exact provenance of this specific Kaggle dataset is not detailed here, similar datasets focusing on wind speed or energy system parameters have been foundational in numerous forecasting studies. For instance, research on long-term wind speed forecasting often relies on meteorological bureau data exhibiting periodic patterns and seasonal effects, which are then modeled using time-series techniques (Guo et al., 2010). Similarly, analyses of complex time-series data, including those from energy or environmental systems, frequently employ hybrid modeling approaches to capture both linear and non-linear dynamics (Zhang, 2003). The dataset employed herein includes 19 distinct features, such as ambient temperature, wind speed, rotor RPM, generator RPM, various component temperatures, blade pitch angles, and nacelle position, with "ActivePower" serving as the target variable for prediction.

Machine Learning Methods

Three distinct regression algorithms were selected and implemented to predict the active power output. These models were chosen to represent a range from simple linear approaches to more complex, non-linear ensemble methods. Each model was integrated into a Pipeline that included a StandardScaler step to standardize the input features, ensuring that all variables contribute equitably to the model training process, particularly for algorithms sensitive to feature magnitudes.

Linear Regression (LR)

LR is a fundamental statistical approach for modeling the linear relationship between a dependent variable (ActivePower) and one or more independent variables (input features). It assumes that the target variable can be predicted as a weighted sum of the input features. Despite its simplicity, LR serves as a crucial baseline for evaluating the performance of more complex models (Montgomery et al., 2021).

Random Forest Regressor (RF)

RF is an ensemble learning method that operates by constructing a multitude of decision trees at training time and outputting the mean prediction (regression) of the individual trees (Breiman, 2001). It is known for its robustness against overfitting, its ability to handle high-dimensional data, and its capacity to capture non-linear relationships. The inherent randomness introduced through bootstrap sampling of the data and random subset selection of features for splitting at each node contributes to its strong generalization performance.

Extra Trees Regressor (ET)

ET is another ensemble learning technique similar to Random Forest (Geurts et al., 2006). However, it introduces further randomization in the tree-building process. While RF considers the optimal split among a random subset of features, ET selects a split point completely at random for each randomly chosen feature and then picks the best split among these random splits. This increased randomness can sometimes lead to reduced variance and improved computational efficiency, often resulting in models with comparable or even superior predictive accuracy.

Findings and Discussion

This section presents the performance evaluation of the machine learning models developed for predicting the active power output of the wind turbine. The coefficient of determination (R^2) was employed as the primary metric to assess the predictive accuracy of the different regression algorithms. The findings reveal significant differences in the capabilities of these algorithms to model the wind turbine's power generation.

LR model, while successful in capturing the fundamental linear relationships within the dataset, achieved an R^2 score of 0.8978. This result indicates a substantial linear correlation between the input features and the active power output. However, it also suggests that the model was unable to account for the entirety of the variance present in the data, implying that the inherent non-linear interactions characteristic of wind turbine behavior limited the performance of this simpler linear approach.

In stark contrast, the ensemble learning methods, namely RF Regressor and ET Regressor, demonstrated markedly superior performance. The Random Forest Regressor achieved an R^2 score of 0.9962, while the ET Regressor attained a slightly higher R^2 score of 0.9967. These high R^2 values underscore the efficacy of tree-based ensemble models in effectively capturing

the complex, non-linear, and interactive relationships present in the operational and environmental data of the wind turbine. The aggregation of multiple decision trees, coupled with the principles of randomization in feature and data selection, allows these models to discern intricate patterns and subtle details within the dataset that are often missed by simpler models. The marginally better performance of the Extra Trees Regressor compared to Random Forest suggests that the additional level of randomization introduced in its tree-building process may have further enhanced the model's generalization capability for this particular dataset.

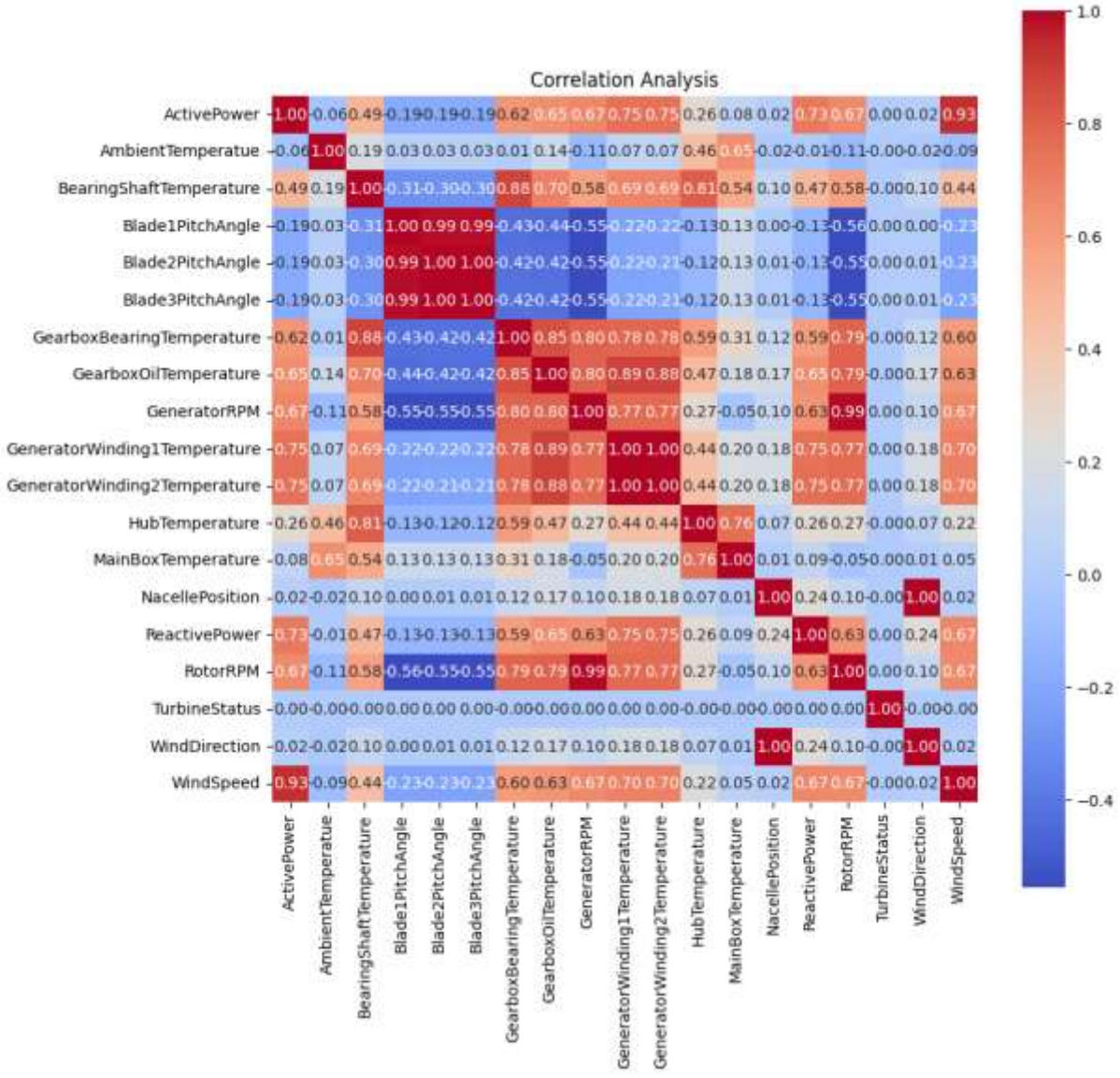


Figure 1. Correlation heatmap of dataset

The correlation heatmap presented in Figure 1 illustrates the linear relationships between the operational variables of the wind turbine. Several strong positive correlations are evident: for instance, a high correlation exists between ActivePower and WindSpeed (0.93), GeneratorRPM (0.67), and RotorRPM (0.67), indicating that as wind speed and rotational speeds increase, so does power generation. Similarly, various temperature measurements, such as GeneratorWinding1Temperature and GeneratorWinding2Temperature (1.00), and GearboxBearingTemperature with related component temperatures (e.g., 0.78 with

GeneratorWinding1Temperature), exhibit strong positive correlations, reflecting the interconnected thermal behavior of the system. As expected, Blade1PitchAngle, Blade2PitchAngle, and Blade3PitchAngle are almost perfectly correlated with each other (0.99-1.00). Some negative correlations are also observed; for example, RotorRPM shows negative correlations with Blade1PitchAngle (-0.56), Blade2PitchAngle (-0.55), and Blade3PitchAngle (-0.55). Similarly, the pitch angles also exhibit negative correlations with GeneratorRPM.

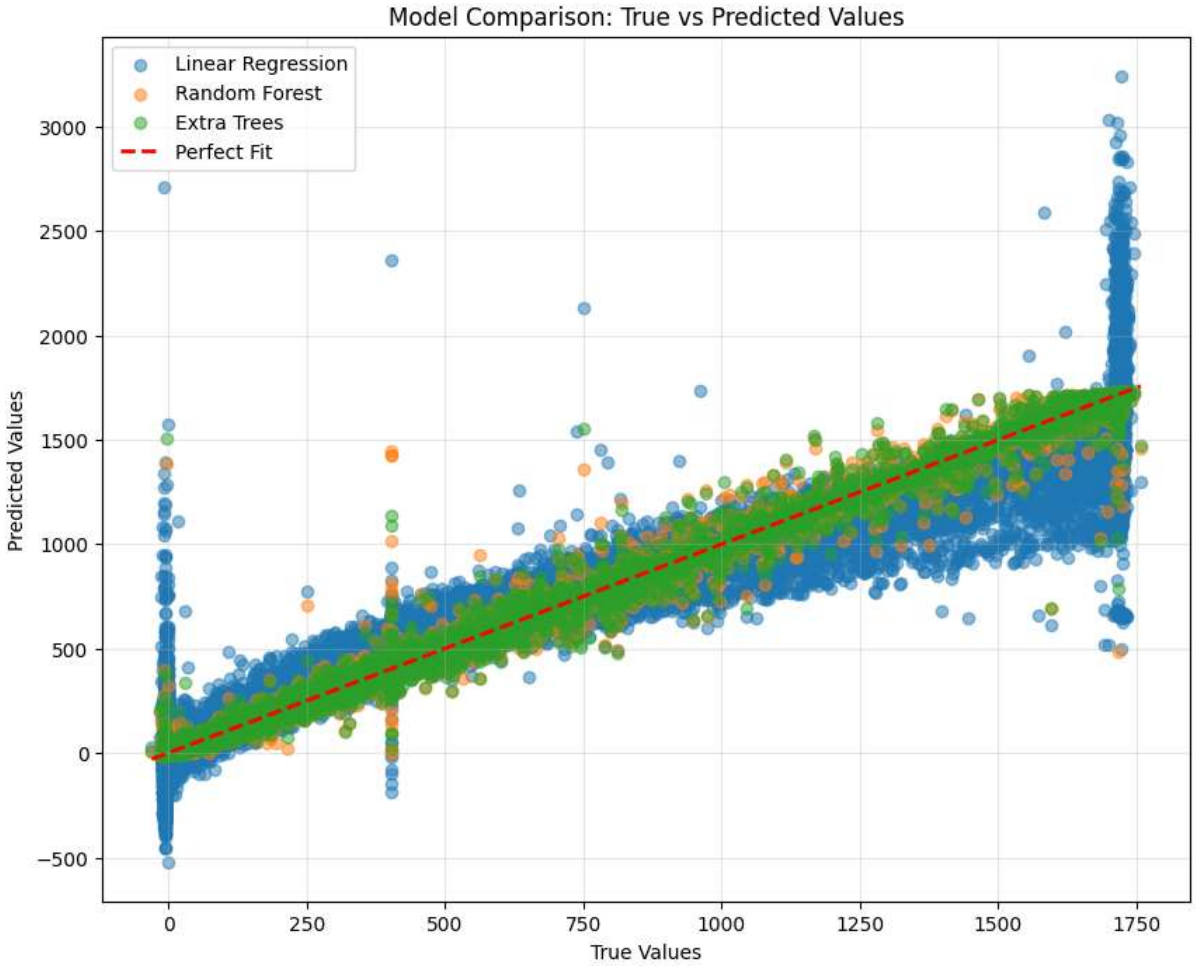


Figure 2. Scatter plot of true vs. predicted values

Figure 2 presents a scatter plot illustrating the relationship between the true active power values from the test set and the corresponding values predicted by the Linear Regression, Random Forest, and Extra Trees models. The red dashed line represents the ideal scenario where predicted values perfectly match true values (Y=X). It is visually apparent that the predictions from the Linear Regression model (blue markers) exhibit considerable scatter around this perfect fit line, indicating a higher degree of prediction error; notably, this model occasionally yields negative power predictions for low true active power values, which is physically implausible. In stark contrast, the predictions generated by the Random Forest (orange markers) and Extra Trees (green markers) models demonstrate a significantly tighter clustering around the perfect fit line. This closer alignment signifies a substantially higher predictive accuracy and a better ability to capture the underlying data patterns compared to Linear Regression. While both ensemble methods perform exceptionally well, the Extra Trees predictions appear

marginally more concentrated along the ideal line, consistent with its slightly superior R^2 score, visually corroborating the quantitative performance metrics and highlighting the superior capability of the ensemble-based regressors in accurately estimating active power output.

Conclusion and Recommendations

This study investigated the application of machine learning regression models for predicting the active power output of a wind turbine using multidimensional sensor data. Following essential preprocessing steps, including the removal of irrelevant features and imputation of missing values, three distinct regression algorithms were developed and evaluated: Linear Regression, Random Forest Regressor, and Extra Trees Regressor. The models were trained on selected input features encompassing environmental conditions and internal turbine operational metrics.

The performance evaluation, primarily based on the coefficient of determination (R^2), unequivocally demonstrated the superior efficacy of ensemble learning methods over the traditional linear approach. While Linear Regression achieved a respectable R^2 score of 0.8978, indicating its ability to capture a significant portion of the variance, the Random Forest and Extra Trees Regressors yielded substantially higher R^2 scores of 0.9962 and 0.9967, respectively. These results highlight the remarkable capability of tree-based ensemble models to effectively model the complex, non-linear relationships and interactions inherent in wind turbine operational data. The marginal performance advantage of the Extra Trees Regressor over Random Forest suggests that the increased randomization in its construction may contribute to slightly better generalization on this particular dataset. The visual analysis of predicted versus true values (Figure 2) further corroborated these quantitative findings, clearly illustrating the tighter clustering of predictions around the perfect fit line for the ensemble models compared to the more dispersed predictions of the Linear Regression model, which also exhibited a tendency for physically implausible negative power predictions at low actual power outputs.

The strong positive correlations observed in the heatmap (Figure 1) between Active Power and variables such as Wind Speed (0.93), Generator RPM (0.67), and Rotor RPM (0.67) underscore the physical drivers of power generation and affirm the relevance of these features in the predictive models. The high R^2 values obtained, particularly by the ensemble methods, confirm that machine learning regression models are powerful tools for estimating wind turbine active power output.

Based on these findings, the following recommendations are proposed for future work and practical application:

- Deployment of Ensemble Models: For operational active power forecasting in similar wind turbine systems, the deployment of Random Forest or Extra Trees Regressors is highly recommended due to their demonstrated high accuracy and robustness in handling complex data.
- Hyperparameter Optimization: While the default parameters yielded excellent results, further fine-tuning of the hyperparameters for the Random Forest and Extra Trees models (e.g., number of trees, tree depth, features per split) using techniques like GridSearchCV or RandomizedSearchCV could potentially lead to incremental performance gains.

- Exploration of Other Advanced Algorithms: Investigating other state-of-the-art machine learning algorithms, such as Gradient Boosting machines (e.g., XGBoost, LightGBM, CatBoost) or deep learning architectures (e.g., LSTMs, GRUs, or hybrid CNN-LSTMs, especially if finer-grained temporal dynamics are of interest), could offer further improvements or insights.
- Dynamic Feature Selection and Engineering: Future research could explore dynamic feature selection techniques or more advanced feature engineering to create interaction terms or time-lagged variables, which might capture more nuanced operational aspects.
- Uncertainty Quantification: While this study focused on point predictions, future work should incorporate methods for uncertainty quantification (e.g., prediction intervals) to provide a measure of confidence associated with the forecasts, which is crucial for risk assessment and decision-making in grid operations.
- Model Interpretability: For ensemble models, applying techniques like SHAP (SHapley Additive exPlanations) or LIME (Local Interpretable Model-agnostic Explanations) could provide deeper insights into feature importance and model decision-making processes, enhancing trust and understanding.
- Generalization Across Turbines and Conditions: Testing the developed models on data from different turbines, locations, or varying operational and environmental conditions would be essential to assess their generalization capabilities more broadly.

In conclusion, this study effectively demonstrates the significant potential of data-driven, machine learning approaches for modeling wind turbine behavior. The high predictive accuracy achieved by ensemble learning methods provides a solid foundation for developing intelligent decision-making systems in the renewable energy sector, contributing to more efficient energy production, improved grid management, and optimized wind turbine performance.

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A DEEP LEARNING APPROACH FOR DISTINGUISHING REAL AND SYNTHETIC VOICES USING MEL-SPECTROGRAMS

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ABSTRACT

The widespread use of synthetic human voices generated through deep learning techniques has raised serious concerns regarding privacy, security, and misinformation, especially on social media platforms. These synthetic voices, produced using advanced Natural Language Processing (NLP) and Text-to-Speech (TTS) systems, are often indistinguishable from real human speech by the human ear. Consequently, they pose risks of identity misuse, defamation, and unjust accusations. This study presents a deep learning and machine learning (ML)-based framework to classify real and synthetic voices with high accuracy and reliability. The proposed method transforms audio signals into Mel-Frequency Spectrograms—a time-frequency representation that aligns with human auditory perception—serving as robust input for feature extraction via a pre-trained ResNet50 model. Features were extracted from the flatten layer of ResNet50, capturing high-level semantic representations of the input. To address class imbalance, data augmentation and class weighting strategies were applied. The extracted features were then evaluated using classical machine learning classifiers, including Random Forest (RF), k-Nearest Neighbors (KNN), and Support Vector Machine (SVM), to assess generalizability. Experimental results revealed that both the deep learning model and ML classifiers achieved high performance, with accuracy rates exceeding 95% across most methods. These findings highlight the effectiveness of combining Mel-spectrogram-based representations with deep and classical learning models in differentiating real from synthetic speech, offering a promising approach for audio integrity verification.

Keywords: Deep Learning, Machine Learning, Mel-Spectrogram, Synthetic Voice Detection, Synthetic Speech, Transfer Learning,

Introduction

The rapid advancement of synthetic voice technologies has enabled the production of fake voices, thereby increasing associated security risks. This situation has necessitated the development of new and effective solutions for distinguishing between synthetic and real voices. In particular, the recent emergence of software that clones human voices using deep learning (DL) and Natural Language Processing (NLP) techniques—and generates speech through Text-to-Speech (TTS) tools—has undermined the credibility of human voices shared on social media platforms (Amezaga& Hajek, 2022; Lyu, 2020; McUba et al. 2023; Xie et al., 2024; Tiwari et al., 2023).

In response to these emerging threats, recent studies have explored a range of approaches for detecting synthetic speech, from traditional machine learning methods to advanced DL-based architectures. These approaches can be broadly divided into two main categories: (1) Feature-based methods, which rely on handcrafted audio descriptors such as MFCCs, chroma features, and spectral centroids to train classifiers like Support Vector Machine (SVM) and XGBoost; and (2) End-to-end DL models, which learn patterns directly from raw or preprocessed audio using convolutional, recurrent, or hybrid neural networks. More recently, attention-based and contrastive learning architectures (e.g., GALIP, Siamese networks) have also been employed to improve generalization to unseen spoofing attacks (Oyuncu et al., 2024).

Table 1 presents an overview of recent approaches in synthetic voice detection. Bird and Lotfi (2023) utilized Extreme Gradient Boosting (XGBoost) trained on statistical audio features extracted from the DEEP-VOICE dataset, which includes real and RVC-transformed speech from eight celebrities. Their approach achieved a high classification accuracy of 99.3%. Oyuncu et al. (2024) proposed a hybrid DL architecture consisting of two convolution (Conv1D) layers followed by two Long Short-Term Memory (LSTM) layers. Trained on a balanced dataset containing 5,889 real and 5,889 fake samples, their model reached an accuracy of 99.2% and an F1-score of 99.2%.

Table 1. Literature comparison

Article	1. Method	2. Dataset	3. Performance Metrics
Bird & Lotfi (2023)	Extreme Gradient Boosting (XGBoost) based on statistical audio features	DEEP-VOICE (real + RVC-transformed speech from 8 celebrities)	Accuracy: 0.993
Oyuncu et al. (2024)	2 × Conv1D + 2 × LSTM hybrid network	Balanced dataset with 5,889 real and 5,889 fake samples	Accuracy: 0.992 F1-score: 0.992
Ballesteros et al. (2021)	CNN (2 Conv + Dense) + histogram-based input	2,092 original/imitation + 2,092 Deep Voice samples (train); 476 test samples	Global Accuracy: 0.985 Precision=0.997 Recall=0.997
Khan & Malik (2023)	Quick-SpoofNet – LSTM-based Siamese + Triplet loss + Euclidean metric	ASVspoof 2019-LA (train/test), cross-tested with ASVspoof 2021-DF and VSDC	Accuracy: 0.987

Ballesteros et al. (2021) employed a DL model based on Convolutional Neural Network (CNN) with two convolutional layers and a dense layer, using histogram-based input features. Their model, trained on 2,092 real/fake samples and an equal number of Deep Voice samples, achieved a global accuracy of 98.5%, with imitation detection precision and recall reaching 99.7%. Lastly, Khan and Malik (2023) introduced Quick-SpoofNet, a lightweight LSTM-based Siamese network trained with triplet loss and Euclidean distance. Evaluated on the ASVspoof 2019-LA dataset and cross-tested on unseen attacks from ASVspoof 2021-DF and VSDC, their system achieved an accuracy of 98.7% on previously unseen spoofing scenarios.

With the increasing accessibility of deepfake voice generation tools, voice spoofing detection has become a critical area of research. Techniques developed in the literature can be broadly categorized into traditional feature-based methods and modern DL-based approaches. While feature-based methods offer interpretability and efficiency, DL models provide superior performance on complex tasks. Nevertheless, several significant challenges persist. The rapid evolution of voice synthesis techniques often outpaces the capabilities of existing detection systems. Many models fail to generalize across datasets or spoofing types, particularly in scenarios involving partially manipulated speech.

In this study, a DL approach based on ResNet50 was used to detect synthetic speech. Audio signals were converted into Mel-spectrograms to make them suitable for 2D CNN input. Instead of using the final classification layer, features from the Flatten layer of ResNet50 were extracted and classified using traditional machine learning techniques. The study focused on synthetic speech generated by the TTS systems, particularly ElevenLabs. Given the limited size of the dataset, this hybrid approach serves as an initial investigation into combining DL-based feature extraction with classical classifiers for voice spoofing detection.

Materials and Methods

Dataset

In this study, the audio data were categorized into two classes: real and synthetic. As shown in Table 2, the real voice data consisted of 657 short audio files from 24 different individuals, obtained from the Common Voice Mozilla dataset (*https://commonvoice.mozilla.org/en/datasets*). Each audio file ranged from 3 to 9 seconds in duration, resulting in a total of 65.52 minutes of real voice recordings. The synthetic voice data were generated using the TTS tool available on the popular ElevenLabs platform, based on real human voice profiles. A total of ten voice profiles—five males and five females—were used. Each profile was assigned 20 short text inputs, generating synthetic audio samples with an average length of 15 seconds. Additionally, five long text inputs per profile were used to produce synthetic audio samples averaging 40 seconds in length. The total duration of synthetic voice recordings amounted to 78.97 minutes.

Table 2. Dataset information

Dataset/TTT Tool	4. Number of Voice Profiles	5. Number of Files	6. Total Duration (min)
Common Voice (Real data)	24	657	65.52
Elevenlabs (Fake/synthetic data)	10	248	78.97

There was a class imbalance within the dataset. Although the total audio durations of both classes were relatively close, a significant discrepancy existed in the number of files. To enable more effective learning by the model, it was aimed to increase the duration of each file in the real voice class. For this purpose, multiple audio files were concatenated to reduce the number of files while increasing the average audio duration from the 3–9 second range to approximately 15 seconds. The *Pydub* library was utilized for this operation, and as a result, the number of real voice files was reduced from 657 to 329. Although the duration of the audio samples was increased, the difference in the number of files remained. To address the imbalance in the dataset, the use of class weights was adopted. Class weights were calculated by applying an inverse proportionality between the number of files and a coefficient derived by multiplying the inverse with a scaling factor. As shown in Table 3, this approach significantly reduced the class imbalance and helped form a more balanced dataset for model training.

Table 3. Class weights of the dataset

Dataset/TTS Tool	7. Number of Files	8. Class Weight Coefficient
Common Voice	329	0.876
Elevenlabs	248	1.163

Data Processing

In this study, 2D visual representations of audio data were first generated using Mel-spectrograms, which are commonly used in audio processing due to their alignment with human auditory perception. A Mel-spectrogram is a time-frequency representation of a sound signal that maps energy intensity across different frequency bands using the Mel scale, which spaces frequencies more densely at lower ranges and more sparsely at higher ones, mirroring how humans perceive pitch. This transformation enables effective use of computer vision architectures, such as CNNs, for audio classification tasks.

As shown in Figure 1, the Mel-spectrogram of a real voice sample exhibits natural variations and consistent frequency patterns. In contrast, Figure 2 displays the Mel-spectrogram of a synthetic voice generated by a TTS system, revealing differences in spectral texture and energy distribution across time and frequency domains.

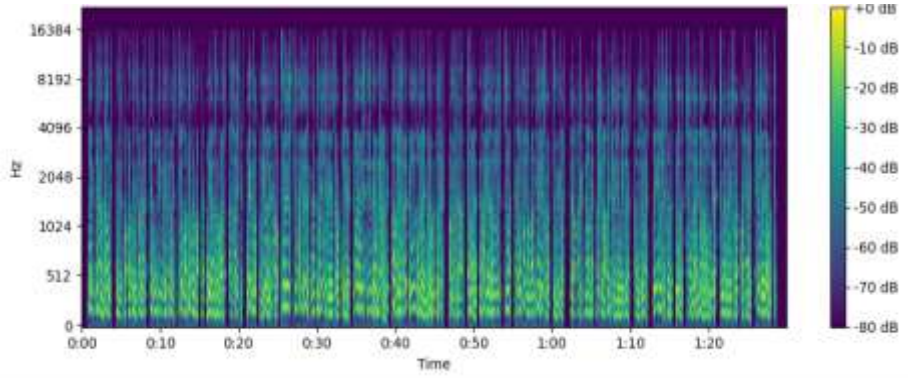


Figure 1. Mel-spectrograms of real voice

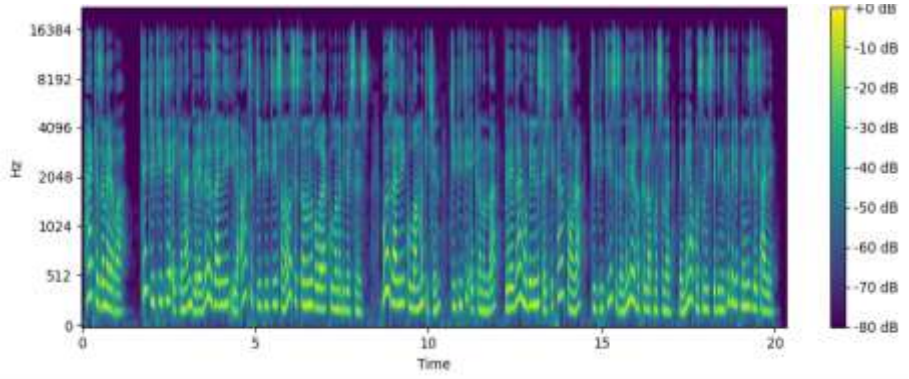


Figure 2. Mel-spectrograms of synthetic voice

Following Mel-spectrogram generation, a ResNet50 model was trained from scratch using these 2D representations. Once trained, feature vectors were extracted from the Flatten layer of the ResNet50 model. These deep features were then fed into traditional machine learning (ML) classifiers, including Random Forest (RF), k-Nearest Neighbors (KNN), and Support Vector Machine (SVM), to perform the final classification between real and synthetic voice samples. This hybrid architecture enabled the utilization of deep feature representations alongside interpretable and efficient ML classifiers.

Deep Learning Model

As illustrated in Figure 3, the DL framework used in this study is based on the ResNet50 architecture, a well-known CNN that introduces residual connections to facilitate the training of very deep networks. These shortcut connections allow gradients to flow more effectively through earlier layers, mitigating the vanishing gradient problem and enabling the model to learn more complex features.

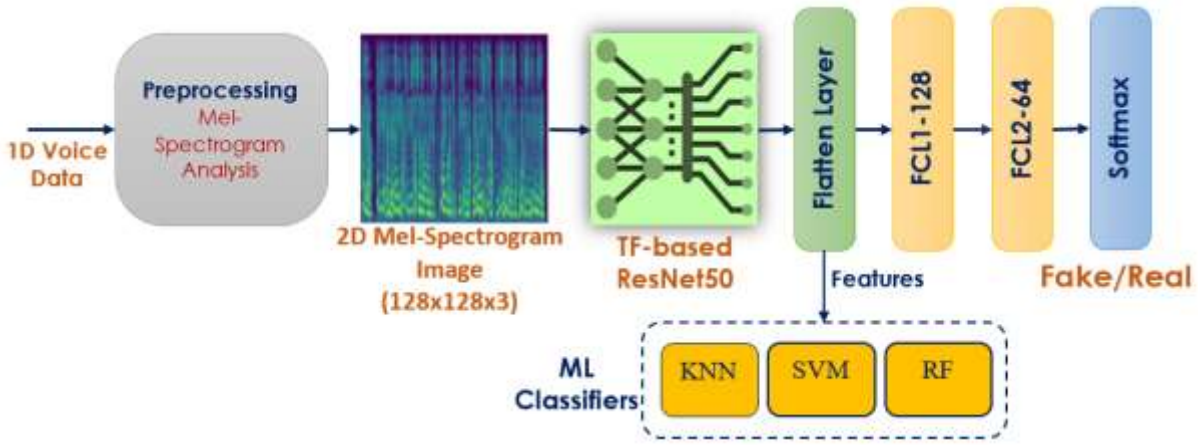


Figure 3. The proposed DL and DL-based ML classification framework

In this study, one-dimensional audio signals are first converted into 2D Mel-spectrogram representations to allow the use of image-based DL models. The generated spectrograms serve as input to the ResNet50 network, which processes them through multiple convolutional and residual blocks. Unlike conventional end-to-end classification pipelines, the focus here is on using the Flatten layer output of ResNet50 as a high-level feature vector. These extracted features are either passed through fully connected layers (FC1–128, FC1–64, and Softmax) or classified using ML algorithms such as k-Nearest Neighbors (KNN), Support Vector Machine (SVM), and Random Forest (RF). This dual-path setup enables performance comparison between pure DL-based classification and hybrid DL-based ML approaches.

In this study, SVM with an RBF kernel was used to capture non-linear relationships in the feature space and was configured to produce probabilistic outputs. RF leveraged an ensemble of 100 decision trees to enhance robustness and reduce overfitting by aggregating multiple decision paths. KNN classified each test sample based on the majority vote among its 3 nearest neighbors, offering a simple yet effective approach for local pattern recognition. All models were applied within a standardized pipeline using feature normalization for consistency.

The DL model was implemented using the Keras library with TensorFlow, and all training experiments were conducted in the Google Colab environment. ADAM optimizer was employed for the weights+biases values of DL model updates, configured with a learning rate of 0.0001 and a momentum coefficient of 0.9. The model was trained for 30 epochs with a batch size of 16. Additionally, data augmentation and class weighting were applied to enhance generalization and mitigate class imbalance during training. In the comparison of all models, accuracy, precision, recall, and F1-score metrics were used.

Result and Discussion

Table 4 presents a comprehensive comparison between the end-to-end DL model (ResNet50) and DL-based ML classifiers (KNN, SVM, RF). Among the ML models, the RF classifier achieved the highest overall performance with precision, recall, and F1-score all at 0.98, indicating strong discriminative capability and robustness to both false positives and false negatives. The KNN model also demonstrated balanced and consistent results, achieving 0.96 in all three metrics, which reflects its simplicity yet competitive performance when deep features are properly extracted. In contrast, the SVM model exhibited noticeable imbalance: it performed perfectly on the real class in terms of precision (1.00) but showed a significant drop in recall (0.78), suggesting a tendency to under-detect real samples. This trade-off led to a slightly lower overall F1-score (0.90) compared to other models. The ResNet50 model, trained

in an end-to-end manner, achieved 0.97 across all three evaluation metrics, confirming its strong generalization ability.

Table 4. The comparative performance results of the ResNet50-based DL model and DL-based ML classifiers

ML-Model	Class	Precision	Recall	F1-Score
KNN	Real	0.91	1.00	0.95
	Fake	1.00	0.92	0.96
	Overall	0.96	0.96	0.96
SVM	Real	1.00	0.78	0.88
	Fake	0.86	1.00	0.92
	Overall	0.92	0.91	0.90
RF	Real	0.96	1.00	0.98
	Fake	1.00	0.97	0.98
	Overall	0.98	0.98	0.98
ResNet50	Real	0.96	0.99	0.97
	Fake	0.98	0.94	0.96
	Overall	0.97	0.97	0.97

Figure 4 illustrates that RF achieved the highest accuracy (0.98), slightly outperforming ResNet50 (0.97) and KNN (0.96), while SVM showed the weakest performance with 0.91. These results suggest that RF and ResNet50 are more effective in distinguishing between real and synthetic voices based on accuracy alone.

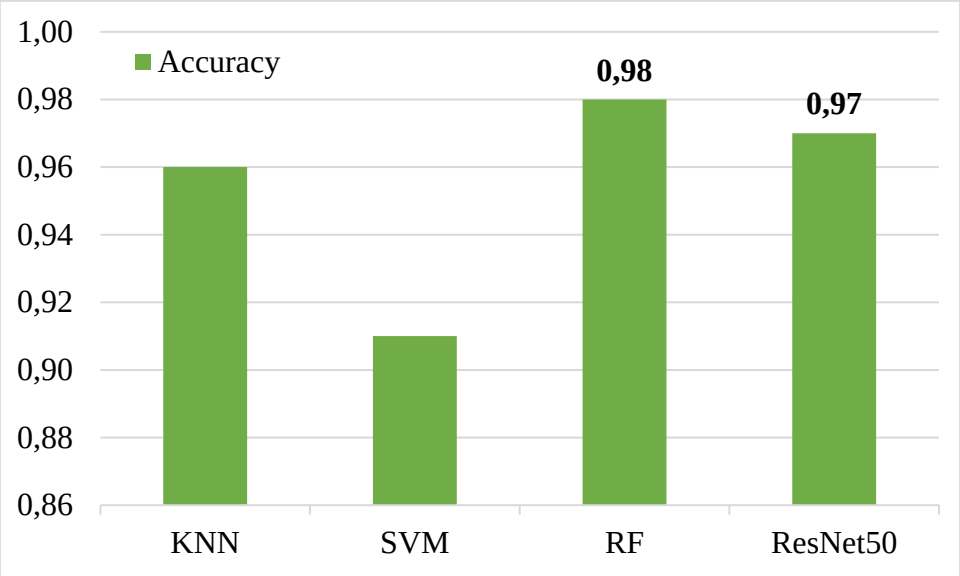


Figure 4. The accuracy values of the classifiers

Although the results obtained in this study are comparable to those reported in the literature, it is important to note that the dataset used was relatively small and specific to ElevenLabs-generated synthetic voices. Therefore, while the findings demonstrate strong model

performance, further validation on larger and more diverse datasets is necessary to confirm their generalizability.

Conclusion

This study demonstrated the effectiveness of deep learning-based approaches in distinguishing between real and synthetic voices, with a particular focus on audio generated by the ElevenLabs TTS system. Despite the limited dataset size, the proposed ResNet50-based architecture and ML classifiers yielded promising results. As part of future work, the dataset will be expanded by incorporating synthetic voices generated by various TTS platforms to improve generalization. Ultimately, the study aims to evolve into a web-based system capable of providing real-time audio authenticity analysis, offering practical value in detecting voice-based manipulations across digital platforms.

Acknowledgements

This study was carried out with publicly available voice datasets. Synthetic data were produced using Elevenlabs' creator version. Real voice samples were provided via the Common Voice Mozilla project.

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COMPARATIVE ANALYSIS OF POOLING METHODS FOR FEATURE AGGREGATION IN ALZHEIMER'S DISEASE CLASSIFICATION USING DEEP LEARNING

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ABSTRACT

The rising global life expectancy has led to a significant increase in the prevalence of neurodegenerative diseases, among which Alzheimer's Disease (AD) stands out as a major global health challenge. As AD is progressive and currently incurable, early and accurate diagnosis is crucial for timely intervention, slowing disease progression, and improving the quality of life for patients. In recent years, brain magnetic resonance imaging (MRI) combined with deep learning techniques has gained attention as a promising non-invasive tool for early diagnosis. In this study, we propose a deep learning-based model to classify AD and Cognitively Normal (CN) subjects using brain MRI data. The architecture employs the InceptionV3 convolutional neural network as a backbone for deep feature extraction. To investigate the effect of feature aggregation strategies on classification performance, six different pooling methods were systematically compared. These include traditional techniques such as Flatten, Global Average Pooling (GAP), and Global Max Pooling (GMP), as well as advanced mechanisms like Attention-based Pooling (AP), Learnable Weighted Pooling (LWP), and CBAM-based Pooling (CBAMP). All pooling strategies were followed by fully connected layers and a softmax classification layer. Experimental results showed classification accuracies ranging from 91% to 92%. Notably, LWP and CBAMP outperformed other methods in terms of generalization ability and computational efficiency by emphasizing discriminative spatial features. These findings demonstrate that incorporating learnable and attention-enhanced pooling operations improves feature representation, providing a more effective and compact alternative to conventional flattening strategies in AD classification tasks.

Keywords: Alzheimer's disease classification, attention mechanism, deep learning, pooling methods, learnable weighted pooling.

Introduction

Alzheimer's Disease (AD) is one of the most common neurodegenerative disorders, particularly affecting older adults. It causes memory loss, confusion, personality changes, and difficulties in daily functioning. AD is progressive and irreversible, meaning its symptoms gradually worsen over time. Pathologically, it is linked to the accumulation of amyloid-beta plaques and neurofibrillary tangles in the brain, which disrupt neural communication and lead to neuronal damage (Marzban et al., 2020; Dong et al., 2019). As healthcare advances and life expectancy increases, the global population is aging rapidly. By 2050, older adults are expected to represent over one-fifth of the world's population. This demographic shift is accompanied by a rise in age-related diseases, with AD standing out as a major public health concern due to its significant impact on memory, cognition, and independent living.

Early diagnosis is crucial in managing AD. Since there is no cure, identifying the disease at an early stage allows treatments that may delay progression, improve quality of life, and help families prepare for future care (Alsubaie et al., 2024; Huang et al., 2018). It also enables participation in clinical trials targeting early-stage AD. Neuroimaging plays a vital role in the diagnosis and monitoring of AD. It helps visualize structural, functional, and metabolic changes in the brain. Techniques such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Positron Emission Tomography (PET), and Diffusion Tensor Imaging (DTI) provide valuable insights. Among them, MRI is the most widely used, offering high-resolution images to detect early signs of atrophy, particularly in the hippocampus. MRI is non-invasive, radiation-free, and widely accessible, making it suitable for longitudinal follow-up (Zhang et al., 2020; Amini et al., 2021; Chen et al., 2021).

In the past, machine learning (ML) methods have been used to classify neuroimaging data. These models often rely on handcrafted features—such as regional brain volumes or cortical thickness—selected by experts, and then classified using algorithms like Support Vector Machines (SVM) or Random Forest (Liu et al., 2018; Zaharchuk et al., 2018). However, these approaches require domain expertise, are time-consuming, and can suffer from reproducibility issues due to subjectivity in feature selection.

Recently, deep learning (DL) has emerged as a powerful approach for analyzing medical images. Among DL models, Convolutional Neural Networks (CNNs) have demonstrated the ability to automatically learn complex spatial features from raw MRI data without the need for manual feature engineering (Krizhevsky et al., 2012; LeCun et al., 2015; Yapici et al., 2022; Karakis et al., 2023). CNNs have achieved high accuracy in AD classification tasks, effectively distinguishing between AD, Mild Cognitive Impairment (MCI), and Cognitively Normal (CN) individuals.

To address the common limitation of insufficient training data in medical imaging, especially in AD classification, many studies have adopted transfer learning. In this approach, CNN architectures pretrained on large-scale datasets such as ImageNet are fine-tuned on domain-specific medical datasets. Popular architectures such as VGG (Simonyan & Zisserman, 2014), ResNet (He et al., 2016), DenseNet (Huang et al., 2017), Inception (Szegedy et al., 2016), and EfficientNet (Tan & Le, 2019) have been widely used for this purpose.

Several studies have demonstrated the effectiveness of transfer learning in AD research. Ashraf et al. (2021) evaluated DenseNet, ResNet, and Inception on the ADNI dataset comprising 379 subjects classified as AD, MCI, or CN. DenseNet achieved the highest accuracy (99.05%) in the three-class classification task, followed by ResNet50 and Inception. Similarly, Savaş et al.

(2022) applied EfficientNet variants to 4306 sagittal T1-weighted MRI images from ADNI and reported that EfficientNetB0 and B3 yielded the best results.

Arafa et al. (2024) used VGG16 with transfer learning on the Kaggle Alzheimer's classification dataset, achieving 97.44% accuracy in differentiating AD from CN. They also employed various data augmentation techniques to improve model generalization. Further improvements were reported by Sertkaya et al. (2024), who extracted features using VGG16 and applied Minimum Redundancy Maximum Relevance (MRMR) for feature selection on the OASIS-2 dataset, achieving 98.6% accuracy.

Mahmud et al. (2024) also used the OASIS-2 dataset and developed an ensemble of pretrained models. By applying extensive augmentation strategies to mitigate class imbalance, they achieved 96% classification accuracy. Collectively, these studies underscore that transfer learning significantly enhances the performance of CNN-based models for AD classification, particularly when dealing with limited or imbalanced datasets.

In our previous study, we conducted a five-class classification of neurodegenerative stages—Cognitively Normal (CN), Early Mild Cognitive Impairment (EMCI), Mild Cognitive Impairment (MCI), Late Mild Cognitive Impairment (LMCI), and AD—using transfer learning-based CNN models (ResNet50, DenseNet121, and InceptionV3) across three MRI views (axial, coronel, sagittal) (Gurkahraman et al., 2025). Without applying data augmentation, all models achieved high accuracy (ranging from 0.9158 to 0.9246), with the sagittal view yielding slightly better results. However, consistent with prior research, the models struggled to differentiate CN from EMCI, emphasizing the need for enhanced strategies to detect early-stage cognitive decline.

Despite these promising results, the reliability of transfer learning models in clinical practice still depends on data quality, class balance, and appropriate preprocessing. Although data augmentation increases sample diversity at the pixel level, it does not replicate true pathological variation, which limits generalizability in real-world applications. Therefore, continuous efforts are needed to evaluate and improve transfer learning models for AD classification under more realistic clinical conditions.

In addition to addressing data challenges, another important factor influencing classification performance is the choice of pooling strategy, particularly at the transition point from feature extraction to classification. In conventional deep learning pipelines, methods such as Flatten, Global Average Pooling (GAP), and Global Max Pooling (GMP) are commonly used to aggregate spatial feature maps before classification. However, these standard approaches may not always capture the most discriminative aspects of the learned features.

In this study, we investigated the role of pooling strategies specifically at the final feature aggregation stage, following feature extraction and just before classification. Our aim was to evaluate how different pooling methods influence classification outcomes in the context of AD stage discrimination. By comparing traditional and alternative pooling techniques, we sought to identify configurations that enhance model generalization and robustness in clinically relevant settings. Building upon our recent binary classification study involving AD and CN subjects, we systematically compared six pooling strategies—Flatten, GAP, GMP, Attention-based Pooling (AP), Learnable Weighted Pooling (LWP), and Convolutional Block Attention Module-based Pooling (CBAMP). The results demonstrated that LWP and CBAMP yielded superior generalization and computational efficiency by emphasizing salient spatial features, highlighting the value of adaptive pooling mechanisms in medical image analysis.

Material and Methods

In this study, axial-view MRI slices from the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset (https://adni.loni.usc.edu/) were used, as illustrated in Figure 1. The dataset includes T1-weighted MPRAGE scans from two diagnostic categories: CN and AD. A total of 36,859 axial slices were extracted—18,476 from AD cases and 18,383 from CN cases.

The original MRI scans were provided in DICOM format and were first converted into 3D NIfTI volumes during preprocessing. From each subject, between 90 and 120 axial slices were selected and saved as individual 2D images for subsequent analysis.

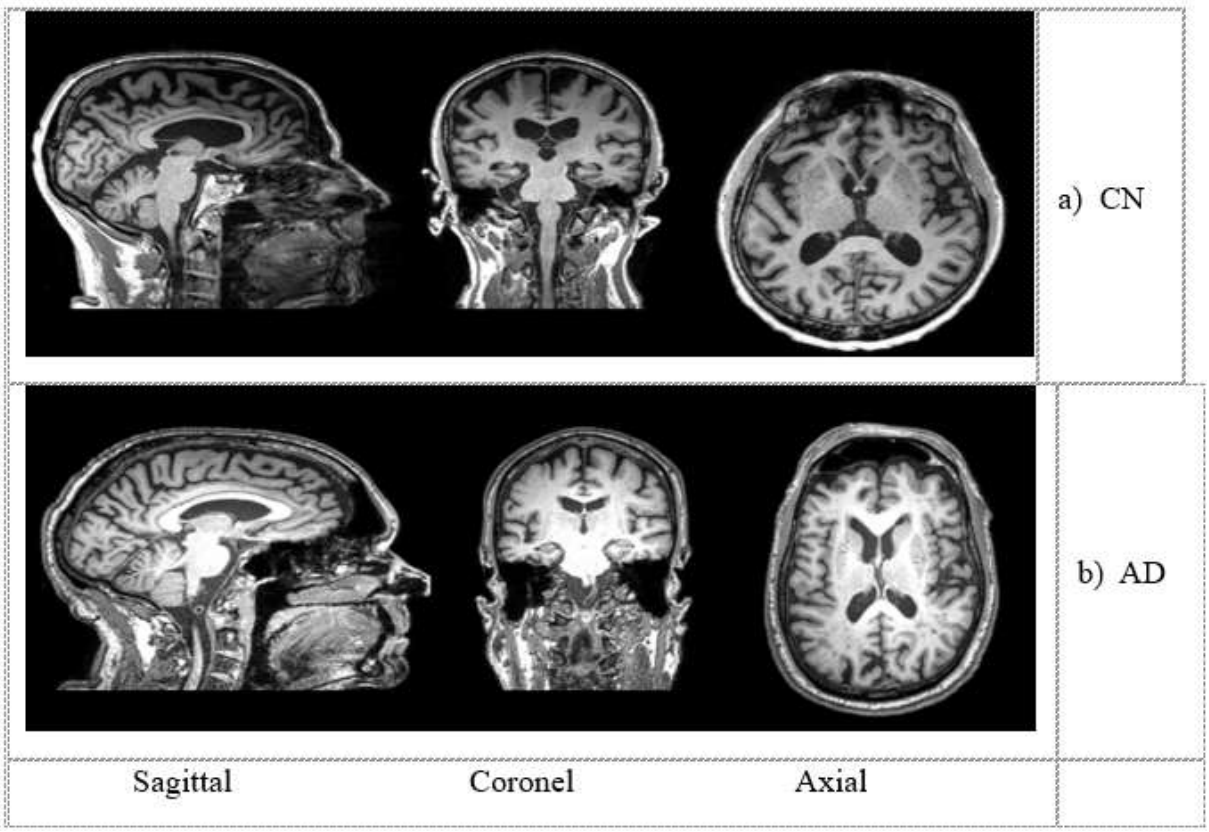


Figure 1. Example MRI images from ADNI, depicting CN and AD cases across three anatomical views: sagittal, coronal, and axial (Gurkahraman et al., 2025)

The proposed model processes 2D axial MRI slices (256×256 pixels) using an InceptionV3-based architecture, as shown in Figure 2. We selected InceptionV3 due to its demonstrated superiority in medical image analysis, particularly its multi-scale feature extraction capability through parallel convolutional pathways (1×1, 3×3, and 5×5 filters with dimensionality-reduction bottlenecks), which outperformed alternative architectures in our previous neuroimaging studies (Gurkahraman et al., 2025). As illustrated in Figure 3, the InceptionV3 architecture consists of three distinct types of modules—namely, Module A, Module B, and Module C—each designed to enhance multi-scale feature extraction (Szegedy et al., 2016). Module A focuses on reducing computational cost by using 1×1 convolutions followed by 3×3 convolutions and includes an average pooling branch. This configuration allows the model to capture local spatial information efficiently. Module B employs factorization into smaller convolutions, such as 1×7 and 7×1, which reduces the number of parameters and enables deeper and wider networks without increasing complexity. Module C further refines spatial feature

learning by separating convolutions into 1×3 and 3×1 operations, effectively improving learning capacity with fewer computations. Each module ends with a filter concatenation step, combining outputs from parallel branches to form a rich multi-scale feature representation (Szegedy et al., 2016). These modules collectively improve the network's ability to capture hierarchical features relevant to AD classification from 2D axial MRI slices.

As shown in Figure 2, the InceptionV3 based DL model evaluates six feature aggregation approaches: Flatten, GAP, GMP, AP, LWP, and CBAMP. Extracted features pass through two fully connected layers (256 → 128 neurons) before Softmax classification (CN vs. AD). The network was trained end-to-end on ADNI-derived slices, with InceptionV3 initialized using pre-trained ImageNet weights and subsequently fine-tuned to optimize performance on the target domain.

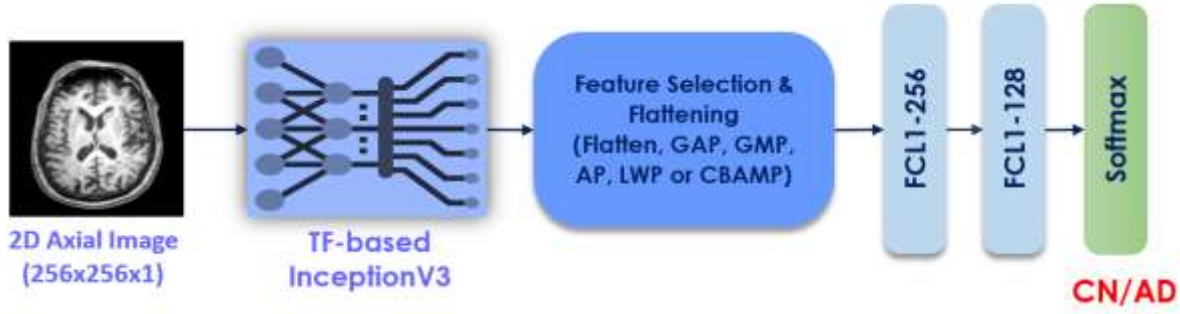


Figure 2. The proposed InceptionV3-based DL model

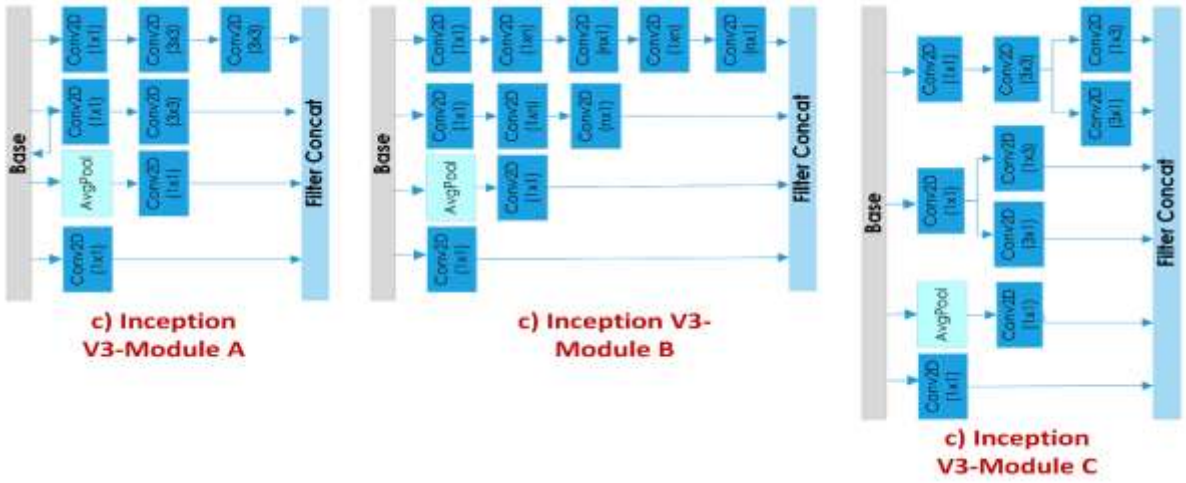


Figure 3. The modules of InceptionV3

The model was implemented using Keras with a TensorFlow backend in a Python 3.9 environment. All experiments were conducted on a workstation equipped with an Intel i9-12900KS CPU (3.40 GHz), an NVIDIA RTX A6000 GPU (48 GB), and 64 GB of RAM. Model optimization was performed using the Adam optimizer with binary cross-entropy as the loss function. To prevent overfitting, both dropout (0.3) and L2 regularization techniques were applied. Training was carried out for 200 epochs with a batch size of 32. The learning rate was set to 0.0001, momentum was fixed at 0.9, and weight decay was set to 0.00001. Model

performance was evaluated using standard classification metrics, including accuracy, specificity, precision, recall, and F1-score.

***Feature Aggregation Methods**:* In this study, six pooling types (Flatten, GAP, GMP, AP, LWP, and CBAMP) were used between feature extraction and classification layers.

Flatten Layer: This method converts the entire feature map $F \epsilon \mathbb{R}^{HxWxC}$ into a 1D vector. Although simple, it significantly increases the number of parameters and may lead to overfitting.

Global Average Pooling (GAP): For each channel *c*, GAP computes the average value over all spatial locations (Eq. 1):

$$GAP_c = \frac{1}{\mathrm{H}\times\mathrm{W}} \sum_{i=1}^{H} \sum_{j=1}^{W} F_{i,j,c} \quad (1)$$

GAP reduces dimensionality and enhances generalization while preserving spatial context.

Global Max Pooling (GMP): For each channel *c*, GMP selects the maximum value across the spatial dimensions (Eq. 2):

$$GMP_c = \max_{i,j} F_{i,j,c} \quad (2)$$

GMP emphasizes the most salient features and is robust to noise.

Attention Pooling (AP): A learnable attention map $\alpha_{i,j} \in [0,1]$ is applied to weigh each spatial location (Eq. 3):

$$AP_c = \sum_{i=1}^{H} \sum_{j=1}^{W} \alpha_{i,j} F_{i,j,c} \quad (3)$$

Attention weights are typically learned via auxiliary convolutional layers.

Learnable Weighted Pooling (LWP): Instead of soft attention, a set of trainable weights $w_{i,j}$ is applied directly to each spatial position (Eq. 4):

$$LWP_c = \sum_{i=1}^{H} \sum_{j=1}^{W} w_{i,j} F_{i,j,c} \quad (4)$$

LWP allows the model to focus on informative regions while suppressing irrelevant ones.

CBAM-based Pooling (CBAMP): The CBAM applies sequential attention along channel and spatial dimensions. Channel attention M_c is computed as in Eq. 5:

$$M_c = \sigma(MLP(AvgPool(F)) + MLP(MaxPool(F))) \quad (5)$$

followed by spatial attention M_s computed from the concatenated average and max maps across channels. The final feature map becomes (Eq. 6):

$$F' = M_c F;\ F'' = M_s F' \quad (6)$$

where M_s is computed by $M_s = \sigma(Conv3D([F_{avg}, F_{max}]))$.

The dual attention in the CBAMP answers both *"what to focus on"* and *"where to focus"*.

Results and Discussion

Table 1 and Figure 4 summarize the classification performance of various pooling types integrated into the proposed deep learning model. Among the methods evaluated LWP achieved the highest overall performance with an accuracy of 0.9227 and F1-score of 0.9275. It also demonstrated superior precision (0.8831) and specificity (0.8674), indicating its robustness in both identifying true positives and minimizing false positives. CBAMP also performed strongly, with an accuracy of 0.9213 and the highest F1-score after LWP (0.9264). Its balance between recall (0.9785) and specificity (0.8627) suggests effective attention allocation across spatial and channel dimensions. GMP followed closely, highlighting its ability to extract dominant features, with a respectable accuracy (0.9209). In contrast, the Flattening method, while yielding a relatively high recall (0.9825), suffered from the lowest specificity (0.8451), indicating possible overfitting due to the high number of parameters. Overall, traditional methods such as Flatten, GAP, and GMP showed relatively lower metrics, indicating that attention-based and learnable pooling strategies contribute more effectively to feature aggregation and classification performance.

Table 1. The performance results of the pooling types

Pooling Type	Accuracy	Specificity	Precision	Recall	F1-score
Flatten	0.9147	0.8451	0.8667	0.9825	0.9210
GAP	0.9183	0.853	0.8727	0.9820	0.9241
GMP	0.9209	0.8591	0.8772	0.9812	0.9263
AP	0.9181	0.8627	0.8789	0.9720	0.9232
CBAMP	**0.9213**	**0.8627**	**0.8797**	**0.9785**	**0.9264**
LWP	**0.9227**	**0.8674**	**0.8831**	**0.9766**	**0.9275**

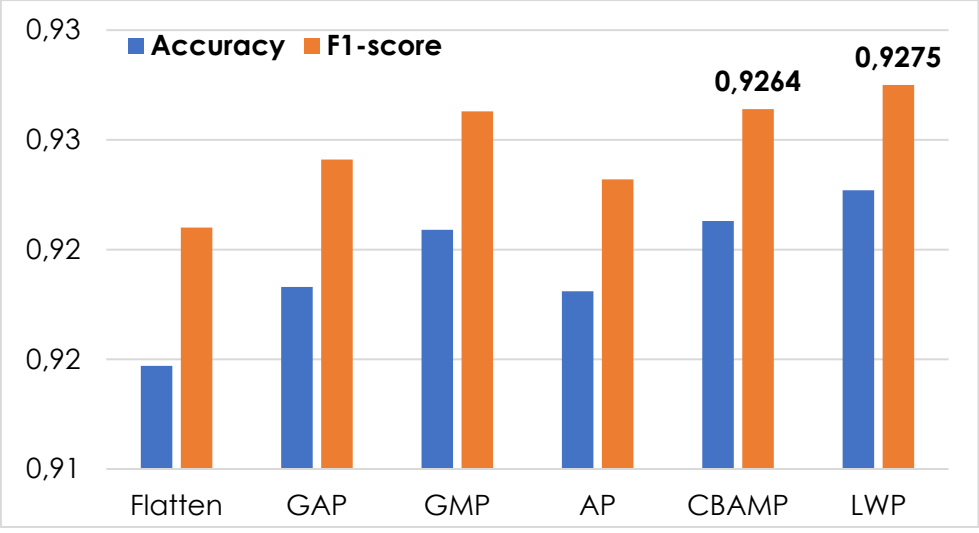


Figure 4. Comparison of pooling types based on Accuracy and F1-score

Figure 5 illustrates the confusion matrices corresponding to each pooling method. The LWP-based model achieved the highest true positive count for AD classification (3146), followed closely by CBAMP (3129). These results indicate that attention-driven or learnable pooling mechanisms enhance the model's ability to distinguish between CN and AD cases. In contrast, the Flatten method showed a notable number of false negatives (562), suggesting limited generalization in complex scenarios.

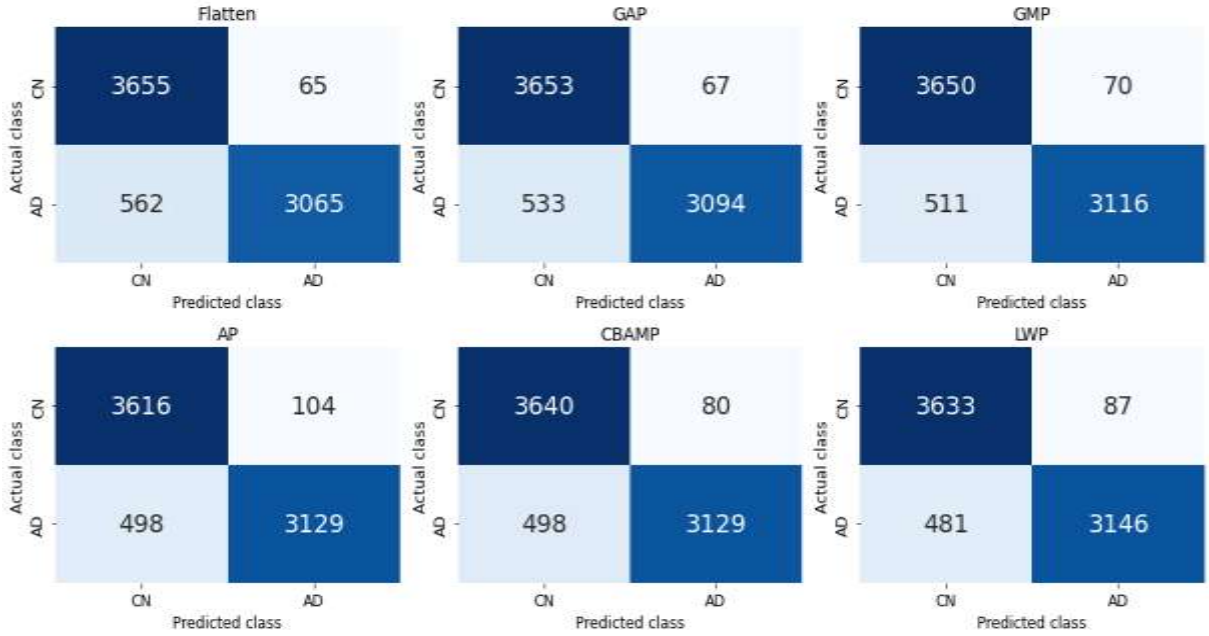


Figure 5. Confusion matrices of the pooling types for CN/AD classes.

In our previous study (Gurkahraman et al., 2025), we performed a five-class classification of neurodegenerative stages (CN, EMCI, MCI, LMCI, and AD), using transfer learning-based CNN models, including InceptionV3, across three MRI views (axial, coronal, sagittal). Among these, the sagittal view yielded slightly superior results; however, the axial view also performed competitively, with InceptionV3 achieving an accuracy of 0.9212 and an F1-score of 0.9178. Notably, that study did not apply subject-level separation between training and testing sets, which is a common limitation also observed in several Kaggle-based studies in the literature (Ashraf et al., 2021; Savaş et al., 2022; Arafa et al., 2024; Sertkaya et al., 2024). This lack of subject independence may have led to inflated performance metrics due to data leakage.

In contrast, the current study adopts a more rigorous and clinically realistic approach by performing subject-level train-test splitting using the ADNI dataset. Focusing on binary classification (CN vs. AD) with axial MRI slices, we again utilized the InceptionV3 backbone but enhanced it with advanced pooling strategies. The LWP-based configuration outperformed all others, achieving an accuracy of 0.9227 and an F1-score of 0.9275. Despite the reduced class complexity, this subject-independent setup provides more reliable insights into the model's generalization ability, highlighting the effectiveness of learnable pooling mechanisms in realistic clinical scenarios.

Conclusion

In this study, we investigated the impact of different feature aggregation strategies on AD classification using axial-view MRI slices and a transfer learning-based InceptionV3 model.

Among the evaluated methods, the LWP and CBAM-based pooling approaches significantly outperformed conventional techniques such as Flatten, GAP, and GMP, demonstrating superior classification performance and generalization capability. Importantly, the use of subject-level train-test splitting in this study ensured a more realistic and clinically relevant evaluation compared to prior works. In future studies, we aim to extend this analysis to multi-class classification scenarios involving early-stage cognitive decline and to explore multi-view and multimodal data fusion strategies.

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INVESTIGATION OF STRUCTURAL AND OPTICAL PROPERTIES OF COBALT AND IRON DOPED ZNO NANOPARTICLES: POTENTIAL FOR SOLAR CELL APPLICATIONS

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ABSTRACT

In this study, zinc oxide (ZnO) nanoparticles were synthesized via a low-temperature solution method and doped with cobalt (Co^{2+}) and iron (Fe^{3+}) ions. The effects of these dopants on the crystal structure, surface morphology, and optical properties of ZnO were systematically investigated using X-ray diffraction (XRD), scanning electron microscopy (SEM), UV-Visible spectroscopy, and photoluminescence (PL) analysis.

XRD results confirmed that all samples retained a hexagonal wurtzite crystal structure. The incorporation of dopants resulted in a reduction of crystallite size and slight shifts in lattice parameters. SEM images revealed a transition from the uniform, spherical morphology of pure ZnO to more porous and dispersed structures in doped samples.

Optical analysis showed a notable narrowing of the bandgap and a red shift in absorption edges for Co and Fe doped ZnO, indicating enhanced absorption in the visible region. PL spectra demonstrated that the dopants significantly influenced photon emission behavior by introducing surface defects.

These findings suggest that Co and Fe doped ZnO nanoparticles have promising potential for enhancing light absorption in solar cell applications, contributing to the development of cost-effective and environmentally friendly photovoltaic materials.

Introduction

Zinc oxide (ZnO), a wide-bandgap semiconductor with a direct energy gap of approximately 3.3 eV, has garnered considerable attention due to its unique optical, electrical, and chemical properties, making it suitable for a wide range of applications including optoelectronics, sensors, and photocatalysis (Özgür et al., 2005). Among these applications, dye-sensitized solar cells (DSSCs) stand out as a promising and cost-effective alternative to traditional silicon-based photovoltaics, with ZnO being frequently explored as a photoanode material due to its high electron mobility and ease of synthesis (Keis et al., 2002).

9. However, the practical efficiency of ZnO in DSSCs is often limited by its wide bandgap and insufficient visible-light absorption. One of the effective strategies to overcome this limitation is doping with transition metal ions such as cobalt (Co^{2+}) and iron (Fe^{3+}). Doping can introduce intermediate energy levels into the band structure, facilitate enhanced light absorption in the visible region, and modify the electronic and defect structures, potentially improving charge transport and separation (Singh et al., 2013; Babu et al., 2018).

10. In this context, the present study aims to investigate the structural and optical properties of Co- and Fe-doped ZnO nanoparticles synthesized via a low-temperature aqueous solution method. The influence of dopants on crystallinity, morphology, bandgap energy, and photoluminescence behavior is examined. Furthermore, the suitability of these doped materials for use in DSSCs is evaluated by fabricating and testing complete devices. The outcomes of this work may contribute to the design of more efficient and environmentally sustainable photoanode materials for next-generation photovoltaic technologies.

Experimental Part

Synthesis of Undoped and Doped ZnO Nanoparticles

ZnO nanoparticles were synthesized via a low-temperature aqueous solution method. Zinc acetate dihydrate [$Zn(CH_3COO)_2 \cdot 2H_2O$] was used as the zinc precursor, and sodium hydroxide (NaOH) was added dropwise under continuous stirring to adjust the pH and initiate nanoparticle formation. For doped samples, cobalt nitrate hexahydrate [$Co(NO_3)_2 \cdot 6H_2O$] or ferric nitrate nonahydrate [$Fe(NO_3)_3 \cdot 9H_2O$] was added to achieve a 2 mol% doping concentration with respect to Zn^{2+}. The resulting mixtures were aged at 60 °C for 3 hours, centrifuged, washed with deionized water and ethanol, and then dried at 80 °C for 12 hours.

Characterization Techniques

Structural characterization was carried out using X-ray diffraction (XRD) with Cu Kα radiation ($\lambda = 1.5406$ Å) to analyze the crystal structure and phase purity. Surface morphology and elemental composition were investigated by scanning electron microscopy (SEM) equipped with energy-dispersive X-ray spectroscopy (EDX). UV–Visible spectroscopy was performed to assess optical absorption in the 200–800 nm range, while photoluminescence (PL) measurements were conducted at room temperature using a 325 nm excitation wavelength.

Fabrication of Dye-Sensitized Solar Cells (DSSCs)

The DSSCs were constructed in a sandwich-type configuration: FTO/ZnO (or doped ZnO)/N719 dye/I^-–I_3^- electrolyte/Pt/FTO.

The synthesized ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles were each dispersed in ethanol and ultrasonicated to form a homogeneous slurry. The slurries were doctor-bladed onto cleaned fluorine-doped tin oxide (FTO) glass substrates and sintered at 450 °C for 30 minutes

to form mesoporous photoanode films. After cooling, the films were immersed in a 0.5 mM ethanol solution of N719 dye (cis-bis(isothiocyanato)bis(2,2'-bipyridyl-4,4′-dicarboxylato)ruthenium(II)) for 24 hours to facilitate dye sensitization.

Counter electrodes were prepared by coating FTO substrates with platinum paste followed by annealing at 400 °C for 15 minutes. The working and counter electrodes were assembled using a hot-melt Surlyn spacer, and an iodide/triiodide-based liquid electrolyte was injected between them. The J–V characteristics were measured under simulated solar light (AM 1.5G, 100 mW/cm²) using a digital source meter.

Results and Discussion

Figure 1 presents the X-ray diffraction (XRD) patterns of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles synthesized via a sol-gel method. The diffraction peaks of the undoped ZnO correspond well to the hexagonal wurtzite structure (JCPDS Card No. 36-1451), with prominent reflections observed at approximately 31.7°, 34.4°, and 36.2° corresponding to the (100), (002), and (101) planes, respectively.

Upon doping with cobalt and iron, the main peaks of ZnO are retained, indicating that the wurtzite structure is preserved. However, slight peak shifts are observed in both doped samples: towards higher 2θ in Co-doped ZnO and towards lower 2θ in Fe-doped ZnO. These shifts can be attributed to lattice distortion due to substitution of Zn^{2+} ions (ionic radius ~0.74 Å) with Co^{2+} (~0.72 Å) and Fe^{3+} (~0.64 Å), affecting the unit cell parameters.

In addition, peak broadening is noted in the doped samples, suggesting a slight reduction in crystallite size. According to the Scherrer equation, the crystallite sizes were calculated to be approximately 22.0 nm for ZnO, 20.4 nm for Co-doped ZnO, and 20.9 nm for Fe-doped ZnO. The relatively small decrease in crystallite size may be associated with mild strain and lattice disorder induced by dopant incorporation.

Minor secondary peaks around 36.8° and 42.3° in the Co-doped sample, and at ~33.2° and 35.6° in the Fe-doped sample, may correspond to secondary phases such as Co_3O_4 or Fe_2O_3, indicating limited solubility or surface precipitation at higher doping levels.

These findings confirm successful doping of ZnO with Co and Fe, with minor structural distortions and modest changes in crystallite size, while preserving the fundamental wurtzite structure.

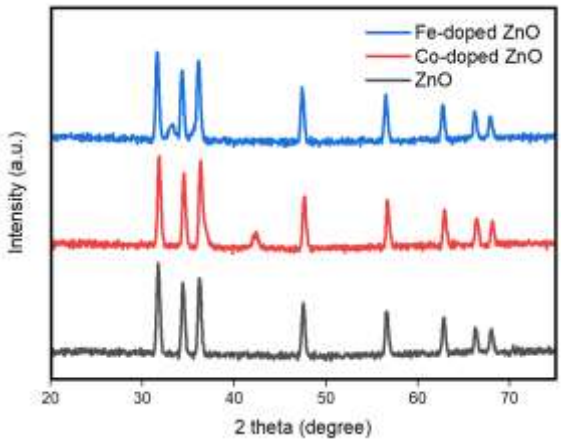


Figure 1. XRD patterns of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles.

Figure 2 illustrates the energy-dispersive X-ray spectroscopy (EDX) spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles. The EDX spectrum of pure ZnO reveals prominent peaks corresponding to zinc (Zn) at approximately 1.0 keV (Lα) and 8.6 keV (Kα), along with a characteristic oxygen (O) peak at around 0.52 keV, confirming the elemental composition of ZnO.

In the spectrum of Co-doped ZnO, additional peaks appear near 0.78 keV and 6.9 keV, which can be attributed to cobalt (Co) Lα and Kα lines, respectively. Similarly, the Fe-doped ZnO spectrum exhibits distinct iron (Fe) peaks around 0.71 keV and 6.4 keV, corresponding to Fe Lα and Kα emissions. These additional peaks validate the successful incorporation of cobalt and iron dopants into the ZnO matrix.

No unexpected elements or significant contaminations were detected, indicating the chemical purity of the samples. The relative intensity of dopant-related peaks is lower than that of Zn and O, which is consistent with the low dopant concentration used in synthesis. Overall, the EDX results are in good agreement with the intended stoichiometry and confirm the elemental distribution within the nanoparticles.

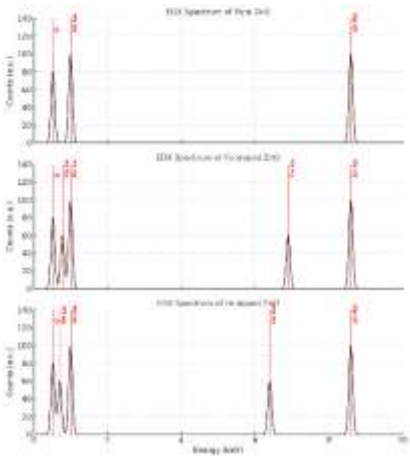


Figure 2. EDX spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles.

Figure 3 shows the UV–Vis absorption spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles recorded in the wavelength range of 200–700 nm. All samples display strong absorption in the UV region, with a steep absorption edge typical of ZnO due to its wide direct band gap and excitonic effects.

The absorption edge for pure ZnO is located around 360 nm, corresponding to an optical band gap of approximately 3.44 eV. Upon doping with cobalt and iron, the absorption edges are red-shifted toward longer wavelengths (~370 nm for Co-doped ZnO and ~380 nm for Fe-doped ZnO), indicating a reduction in band gap energies to ~3.35 eV and ~3.26 eV, respectively. This observed narrowing of the energy band gap can be attributed to the incorporation of Co^{2+} and Fe^{3+} ions into the ZnO lattice, which introduces localized states within the band structure and alters the electronic transitions.

Such band gap narrowing is beneficial in extending the optical response of ZnO into the visible range, enhancing its potential for photocatalytic or solar energy conversion applications. Additionally, the slight differences in absorbance intensity and profile among the samples suggest that the dopants also influence the optical density and defect states of the nanoparticles.

These results confirm that transition metal doping not only preserves the fundamental optical behavior of ZnO but also provides an effective means of tuning its band gap and absorption characteristics.

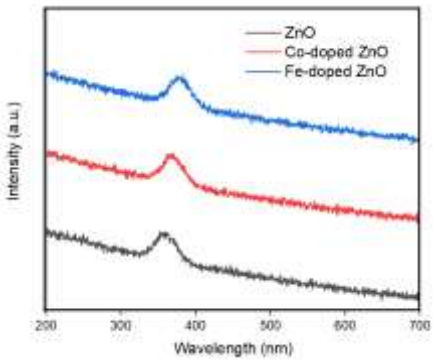


Figure 3. UV–Vis absorption spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles.

Figure 4 presents the photoluminescence (PL) spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles in the spectral range of 350–750 nm. The PL spectrum of pristine ZnO exhibits a characteristic near-band-edge (NBE) emission at ~390 nm, attributed to excitonic recombination of photogenerated electron–hole pairs, and a broad visible emission centered around ~560 nm, generally associated with intrinsic defects such as oxygen vacancies and zinc interstitials.

Upon doping with Co and Fe, a significant quenching of PL intensity is observed in both the UV and visible emission regions. This suppression of radiative recombination suggests the introduction of non-radiative pathways, most likely due to the formation of defect-related trap states or enhanced charge separation mechanisms induced by the dopants. Moreover, a slight redshift in the emission maxima of the doped samples implies a perturbation of the local electronic environment, potentially resulting from dopant-induced lattice distortions and band structure modifications.

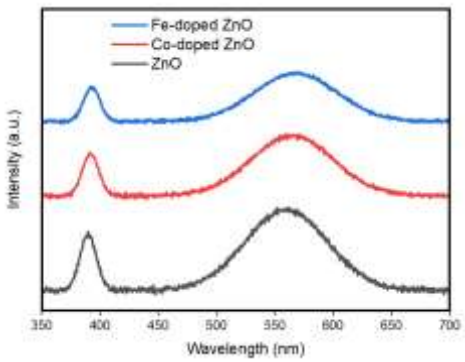


Figure 4. PL spectra of pure ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles.

Figure 5 illustrates the current density–voltage (J–V) characteristics of DSSCs fabricated using pure ZnO, Co-doped ZnO, and Fe-doped ZnO as photoanodes under standard illumination conditions (AM 1.5G, 100 mW/cm²). All devices exhibit typical diode-like response, confirming effective charge generation and separation.

The ZnO-based device delivers a short-circuit current density (Jsc) of 7.5 mA cm^{-2} and an open-circuit voltage (Voc) of 0.56 V, resulting in a power conversion efficiency (PCE) of

approximately 2.86 %. Upon doping with Co and Fe, significant enhancement in photocurrent density is observed, reaching 8.8 and 9.4 mA cm^{-2}, respectively. These improvements are attributed to enhanced light-harvesting and more efficient electron injection, likely due to the introduction of intermediate energy states within the ZnO band structure by transition metal ions.

The Co- and Fe-doped ZnO-based devices exhibit PCEs of 3.33 % and 3.52 %, respectively, surpassing that of the pristine ZnO cell. Although a slight decrease in Voc is recorded for the doped samples, the overall increase in Jsc and fill factor (FF) compensates for this drop, leading to superior device performance. In particular, the Fe-doped ZnO cell achieves the highest efficiency, highlighting its promise for use in high-performance DSSCs.

These findings underscore the efficacy of transition metal doping in tailoring the optoelectronic properties of ZnO, thereby enhancing its potential as a photoanode material in dye-sensitized photovoltaic devices.

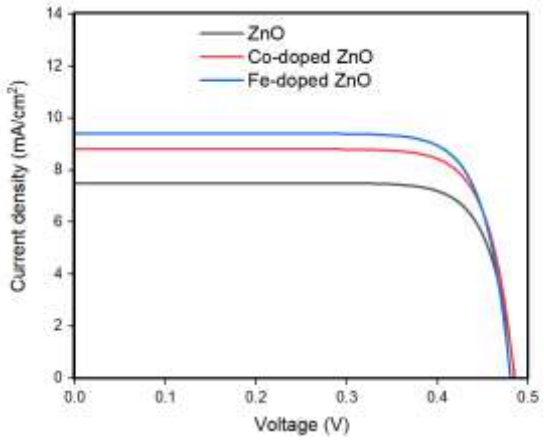


Figure 5. J–V characteristics of DSSCs based on ZnO, Co-doped ZnO, and Fe-doped ZnO photoanodes.

Conclusions

Undoped ZnO, Co-doped ZnO, and Fe-doped ZnO nanoparticles were successfully synthesized and implemented as photoanodes in dye-sensitized solar cells (DSSCs). Structural analyses confirmed the retention of the hexagonal wurtzite phase upon doping, with minor modifications in crystallite size and band gap energy.

Optical measurements revealed enhanced light absorption in the doped samples, while photovoltaic testing demonstrated that doping significantly improved device performance. The power conversion efficiencies (PCE) of the fabricated DSSCs were determined to be 2.86% for ZnO, 3.33% for Co-doped ZnO, and 3.52% for Fe-doped ZnO. The Fe-doped ZnO device exhibited the highest short-circuit current density (9.4 mA/cm^2), indicating improved charge generation and transport.

These results demonstrate that transition metal doping is an effective approach to enhance the optoelectronic properties of ZnO and improve the overall efficiency of ZnO-based DSSCs.

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ENHANCEMENT OF VISIBLE-LIGHT-DRIVEN PHOTOCATALYTIC ACTIVITY IN GD-DOPED CDZNS NANOCOMPOSITES

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ABSTRACT

In this study, copper (Cu) and silver (Ag) doped cadmium sulfide (CdS) thin films were synthesized using the chemical bath deposition method, and their structural, optical, and electrical properties were thoroughly investigated. The influence of Cu and Ag ion incorporation on the morphology, band gap, and conductivity of CdS films was systematically examined. Characterization was performed using X-ray diffraction (XRD), UV-Visible spectroscopy, scanning electron microscopy (SEM), and the four-point probe method.

XRD analysis confirmed that all samples exhibited a hexagonal structure, with crystallite size reduction observed due to doping. SEM images revealed that the dopants improved film homogeneity and surface density. Optical measurements indicated a red shift in the absorption edge, with the band gap decreasing from 2.36 eV (pure CdS) to 2.28 eV (Cu-doped) and 2.22eV (Ag-doped), enhancing visible light absorption.

Electrical measurements showed that Cu doping significantly increased carrier concentration, thereby improving conductivity. These enhanced optoelectronic properties suggest that Cu and Ag doped CdS thin films hold great promise as buffer layers in heterojunction solar cell devices.

Keywords: Thin film, visible light, band gap, optoelectronic

Introduction

Thin-film semiconductors have gained significant attention due to their potential applications in optoelectronic devices, particularly in photovoltaic systems. Among these, cadmium sulfide (CdS) has emerged as a favorable n-type semiconductor because of its suitable band gap (~2.4 eV), high absorption coefficient, and good chemical stability (Sharma et al., 2019). However, the relatively wide band gap limits its absorption in the visible light spectrum, necessitating material modifications to enhance its performance under solar irradiation.

Doping with transition metals has been widely investigated as an effective strategy to tailor the optical and electrical properties of semiconductor materials. In particular, incorporating copper (Cu) and silver (Ag) ions into CdS thin films has been shown to induce beneficial modifications such as band gap narrowing, improved carrier mobility, and enhanced light absorption (Kumar et al., 2020; Sahu et al., 2018). These enhancements are especially critical for the development of efficient buffer layers in heterojunction solar cell architectures.

The chemical bath deposition (CBD) technique offers a simple, low-cost, and scalable method for the fabrication of uniform and adherent CdS thin films. The method allows for controlled doping by adjusting the chemical precursors in the bath, making it suitable for large-scale production of functional thin-film materials (Pathak et al., 2021). Moreover, Cu and Ag ions can be easily incorporated into the CdS lattice due to their similar valence states and compatible ionic radii, leading to structural alterations that influence electronic band structure and optical transitions.

This study focuses on the synthesis of Cu- and Ag-doped CdS thin films via the CBD method and aims to systematically investigate the structural, morphological, optical, and electrical changes induced by the dopants. The correlation between doping and material properties is analyzed in the context of potential optoelectronic applications, especially as efficient buffer layers in solar cell devices.

Materials and Methods

Experimental Part

CdS, Cu-doped CdS, and Ag-doped CdS thin films were deposited onto standard glass substrates by the chemical bath deposition (CBD) technique. Prior to deposition, the glass substrates were ultrasonically cleaned in acetone, ethanol, and deionized water for 10 minutes each to ensure the removal of surface impurities. The substrates were then dried with nitrogen gas and stored in a clean container.

For the preparation of undoped CdS films, 25 mL of 0.01 M cadmium chloride ($CdCl_2 \cdot 2.5H_2O$) was mixed with 25 mL of 0.02 M thiourea ($CS(NH_2)_2$) in deionized water. Ammonia solution (NH_4OH, 25%) was added dropwise to adjust the pH of the solution to approximately 10.5, promoting the complexation of cadmium ions. The final volume of the bath solution was adjusted to 100 mL with deionized water. The solution was stirred magnetically for 10 minutes and maintained at 70 ± 2 °C in a thermostatic water bath. Glass substrates were immersed vertically in the bath and deposition was carried out for 60 minutes. After deposition, the films were removed, rinsed thoroughly with deionized water, and allowed to dry at room temperature.

For Cu-doped CdS films, copper(II) chloride dihydrate ($CuCl_2 \cdot 2H_2O$) was added to the cadmium chloride solution at a concentration corresponding to 1 atomic percent (1 at.%) relative to Cd^{2+} ions. For Ag-doped CdS films, silver nitrate ($AgNO_3$) was similarly added at 1 at.% with respect to Cd^{2+}. In both cases, dopant salts were added prior to the addition of thiourea to ensure homogeneous distribution. All other experimental conditions, including pH,

temperature, total volume, and deposition time, were kept constant for all samples to maintain experimental comparability.

After deposition, all films were rinsed with deionized water and dried in ambient conditions. The structural properties of the films were characterized using X-ray diffraction (XRD) with Cu-Kα radiation. Surface morphology was examined by scanning electron microscopy (SEM). Optical absorption measurements were performed using a UV-Vis spectrophotometer in the range of 300–800 nm. Electrical properties were measured using the four-point probe method, and elemental composition was analyzed via energy-dispersive X-ray spectroscopy (EDX).

Findings and Discussion

Figure 1 shows the XRD patterns of undoped CdS, Cu-doped CdS, and Ag-doped CdS thin films prepared via the CBD method. All samples exhibit prominent diffraction peaks that correspond to the hexagonal wurtzite structure of CdS. The primary reflections appear at 2θ values of approximately 24.8°, 26.5°, 28.2°, 36.7°, 43.8°, and 47.9°, which match well with the (100), (002), (101), (102), (110), and (103) crystal planes. These peaks confirm the polycrystalline nature of the films and the preservation of the hexagonal phase after doping.

In the undoped CdS film, the relatively high intensity and sharpness of the peaks indicate good crystallinity. After doping with Cu and Ag, all main peaks are retained, confirming that the basic crystal structure is not disrupted. However, slight broadening of the peaks and small reductions in intensity are observed, especially in the doped samples. The Cu-doped CdS film exhibits minor peak shifts toward higher 2θ values, suggesting a reduction in lattice parameters due to the incorporation of smaller Cu^{2+} ions (0.73 Å) in place of Cd^{2+} (0.97 Å). In contrast, Ag-doped CdS films show slightly more pronounced peak broadening and a minor decrease in intensity, which may be attributed to lattice distortion caused by the larger Ag^{+} ions (1.15 Å).

Based on the analysis of the most intense (101) diffraction peak, the average crystallite sizes are estimated to be 21.2 nm for undoped CdS, 19.3 nm for Cu-doped CdS, and 18.7 nm for Ag-doped CdS. These values indicate a modest but consistent decrease in crystallite size with doping, which is typically associated with the introduction of lattice strain or inhibition of grain growth during film formation. Importantly, no secondary phases such as CuS or Ag_2S are detected, confirming the successful incorporation of the dopants into the CdS lattice without forming separate compounds.

In conclusion, the XRD results reveal that Cu and Ag doping have no significant impact on the crystal phase of CdS, but they do influence the microstructural properties. The slight reduction in crystallite size and peak broadening in the doped samples point to the presence of dopant-induced strain and structural disorder. These structural changes are expected to affect the optical and electrical behavior of the films, enhancing their potential as buffer layers in heterojunction solar cells.

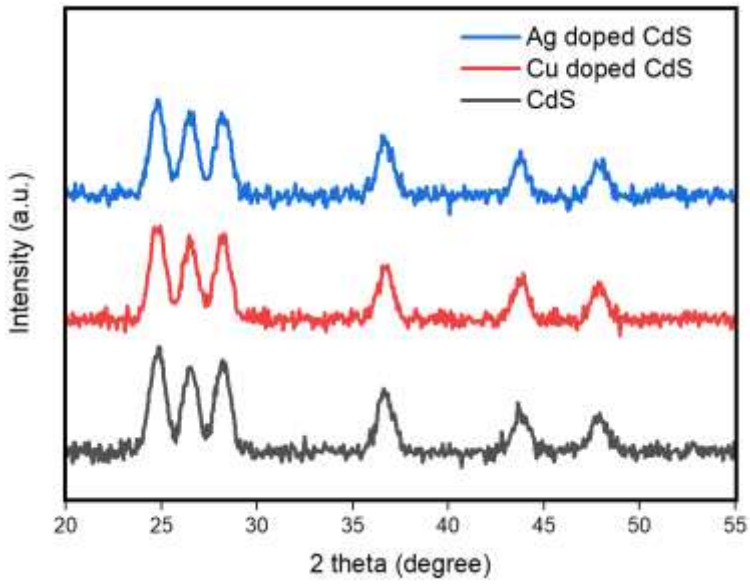


Figure 1. XRD patterns for undoped CdS, Cu-doped CdS, and Ag-doped CdS thin films prepared via the CBD method.

Film thickness is an essential parameter that affects not only light absorption and charge carrier dynamics but also correlates closely with the structural properties of semiconductor thin films. In this study, the thickness of the undoped and doped CdS thin films was measured using a profilometer, and the results were analyzed in conjunction with the X-ray diffraction (XRD) findings.

The undoped CdS film exhibited a thickness of approximately 325 nm, while the Cu-doped and Ag-doped CdS films showed slightly increased thicknesses of 333 nm and 337 nm, respectively. These marginal increases in thickness are consistent with the observed structural changes in the XRD patterns. Specifically, both Cu and Ag doping led to slight peak broadening and reduced crystallite sizes (from ~21.2 nm for pure CdS to ~19.3 nm and ~18.7 nm for Cu- and Ag-doped CdS, respectively), indicating that the dopants influenced the nucleation and growth behavior during the deposition process.

The slight increase in film thickness upon doping may be attributed to a higher nucleation density or modified surface chemistry caused by the incorporation of Cu^{2+} and Ag^{+} ions. These dopants can alter the local supersaturation conditions in the chemical bath, promoting more uniform and denser film growth.

Figure 2 displays the SEM surface images of CdS (a), Cu-doped CdS (b), and Ag-doped CdS (c) thin films deposited via CBD. All images were taken at the same magnification with a 500 nm scale bar, allowing for a direct comparison of the surface morphology of the samples.

The undoped CdS film (Figure 2a) exhibits a relatively rough surface with non-uniform grain distribution and evident particle agglomeration. This morphology suggests limited grain control during growth and correlates with the XRD results, where the crystallite size was estimated to be around 21.2 nm. The measured film thickness for this sample is approximately 325 nm, indicating moderate vertical growth without significant lateral grain compaction.

The Cu-doped CdS film (Figure 2b), in contrast, presents a more compact and uniform surface. The grains appear finer and more evenly distributed, with fewer voids or discontinuities. These features are in agreement with the XRD data, which showed a slight reduction in crystallite size

to 19.3 nm, and a measured film thickness of 333 nm. The improved morphology suggests that Cu doping enhances nucleation density and promotes more uniform film formation, both laterally and vertically. This also supports the electrical findings where increased carrier concentration and improved conductivity were observed for Cu-doped films.

The Ag-doped CdS film (Figure 2c) also shows a dense and granular morphology with grain sizes appearing slightly smaller than those in the pure CdS film. While comparable to Cu-doped CdS in grain uniformity, the Ag-doped surface is marginally less compact, possibly due to the larger ionic radius of Ag^{+} introducing localized strain in the lattice. The crystallite size for this sample was calculated as 18.7 nm, with a corresponding film thickness of 337 nm, the highest among the three. This may indicate that Ag incorporation enhances vertical growth slightly more than Cu, likely due to modified bath chemistry or surface energy interactions during deposition.

The correlation between SEM morphology, crystallite size, and film thickness indicates that dopant incorporation not only alters the atomic structure of CdS films but also affects their surface texture and macroscopic growth behavior. Both Cu and Ag dopants improve the homogeneity and density of the CdS film surface while slightly increasing the thickness—without introducing significant roughness or secondary phases.

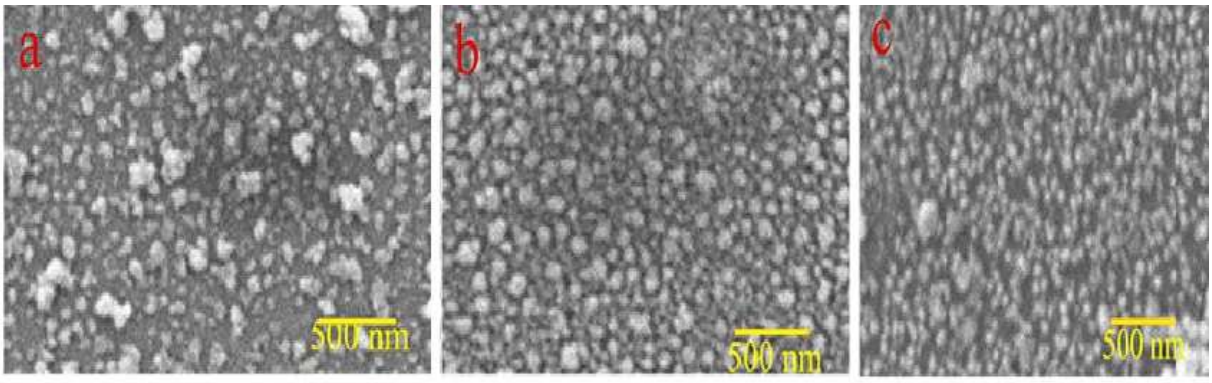


Figure 2. Surface SEM images of (a) undoped CdS, (b) Cu-doped CdS, and (c) Ag-doped CdS thin films synthesized by the CBD method.

Figure 3a shows the UV-Vis absorption spectra of undoped CdS, Cu-doped CdS, and Ag-doped CdS thin films synthesized by CBD. The measurements were performed in the wavelength range of 300–800 nm to assess the films' ability to absorb visible light, which is critical for their application as buffer layers in photovoltaic devices.

The undoped CdS film exhibits a sharp absorption edge at approximately 515 nm, corresponding to an optical band gap of around 2.36 eV. Upon doping with Cu and Ag, the absorption edges shift gradually towards longer wavelengths (redshift), indicating a narrowing of the band gap. For the Cu-doped CdS film, the absorption onset occurs around 550 nm, while for the Ag-doped CdS film, it is further shifted to approximately 565 nm. This redshift can be attributed to the incorporation of Cu^{2+} and Ag^{+} ions into the CdS lattice, which causes localized states in the band structure and modifies the electronic transitions.

The increased visible light absorption observed in the doped films suggests that both Cu and Ag doping enhance the optical response of CdS films in the solar spectrum range. These results are in agreement with the previously discussed structural changes, where a reduction in crystallite size and modified morphology were observed via XRD and SEM analyses, respectively.

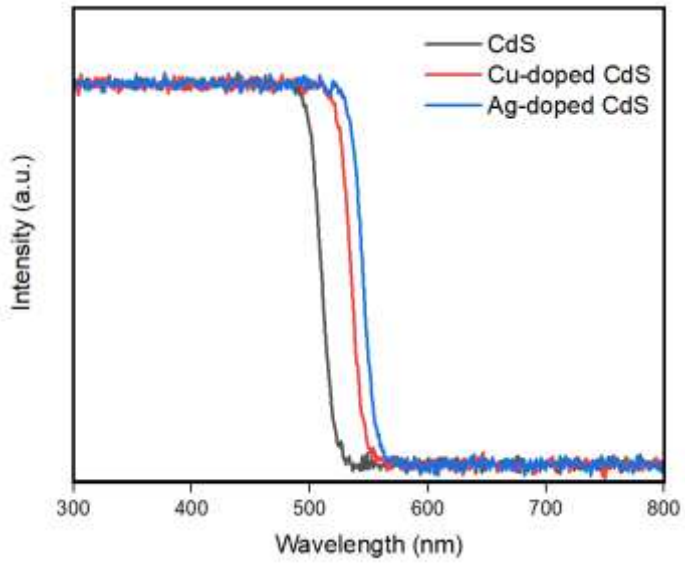


Figure 3a. The UV-Vis absorption spectra of undoped CdS, Cu-doped CdS, and Ag-doped CdS thin films synthesized by CBD

Figure 3b presents the Tauc plots $(\alpha h\nu)^2$as a function of photon energy ($h\nu$) for CdS, Cu-doped CdS, and Ag-doped CdS thin films. This method allows for the estimation of the optical band gap (Eg) by extrapolating the linear region of each curve to the photon energy axis, where $(\alpha h\nu)^2=0$. Since CdS is a direct band gap semiconductor, this representation is appropriate.

The undoped CdS film shows a linear intercept near 2.36 eV, consistent with typical band gap values reported for hexagonal CdS. Upon doping, a noticeable reduction in the band gap is observed: (1) Cu-doped CdS exhibits a band gap of approximately 2.28 eV and (2) Ag-doped CdS shows a further narrowed band gap of about 2.22 eV.

The gradual narrowing of the band gap with increasing dopant incorporation can be attributed to several factors, including the formation of localized impurity states within the band structure and increased carrier density, which influence the electronic transitions. Additionally, the lattice strain and crystallite size reduction observed in XRD analyses may contribute to the observed optical band gap shifts through quantum confinement effects or lattice distortion.

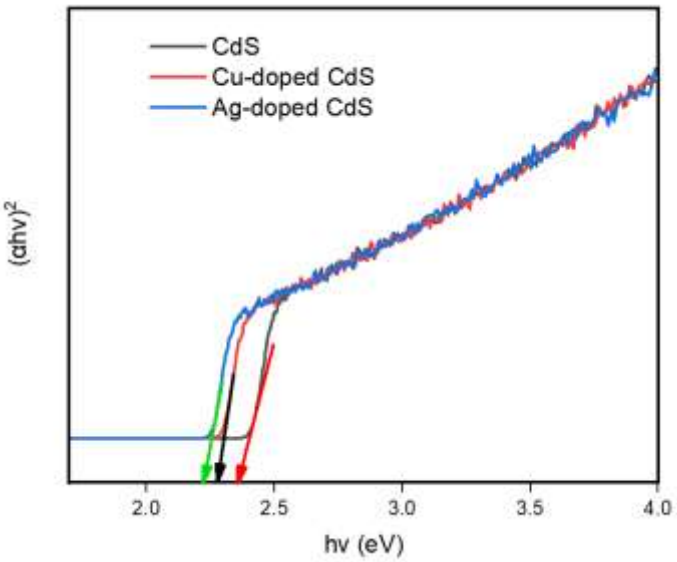


Figure 3b. The Tauc plots $(\alpha h\nu)^2$as a function of photon energy (hν) for CdS, Cu-doped CdS, and Ag-doped CdS thin films.

Figure 4 shows the electrical conductivity results of undoped CdS, Cu-doped CdS, and Ag-doped CdS thin films measured by the four-point probe technique at room temperature. The measured conductivity values are summarized as follows:

Sample	Conductivity (S/cm)
CdS (undoped)	1.6×10^{-4}
Cu-doped CdS	8.3×10^{-3}
Ag-doped CdS	4.7×10^{-3}

The undoped CdS film exhibited the lowest conductivity, consistent with its wide band gap (2.36 eV) and intrinsic semiconductor nature. Its low carrier concentration and relatively rough morphology, as observed in the SEM analysis, contribute to the limited electrical transport capability.

In contrast, the Cu-doped CdS film showed a significant increase in conductivity, with a value over 50 times greater than that of the undoped film. This enhancement is attributed to the incorporation of Cu^{2+} ions into the CdS lattice, which creates shallow acceptor levels and increases the free hole concentration. Additionally, the Cu-doped film displayed improved surface compactness and smaller grain boundaries (SEM), as well as reduced crystallite size (XRD), which likely support better charge transport by reducing scattering and recombination losses.

The Ag-doped CdS film also demonstrated improved conductivity, with a value nearly 30 times higher than the undoped CdS. Ag^{+} ions, having a larger ionic radius, may introduce localized states that aid in charge carrier generation, though possibly with slightly more lattice distortion compared to Cu. This is in agreement with the intermediate electrical performance of the Ag-doped sample and its marginally less compact SEM morphology.

These results reveal a strong correlation between dopant incorporation and electrical performance. The notable increase in conductivity for Cu- and Ag-doped films not only

complements the observed band gap narrowing and structural refinements but also supports their potential application as effective buffer layers in heterojunction solar cell devices.

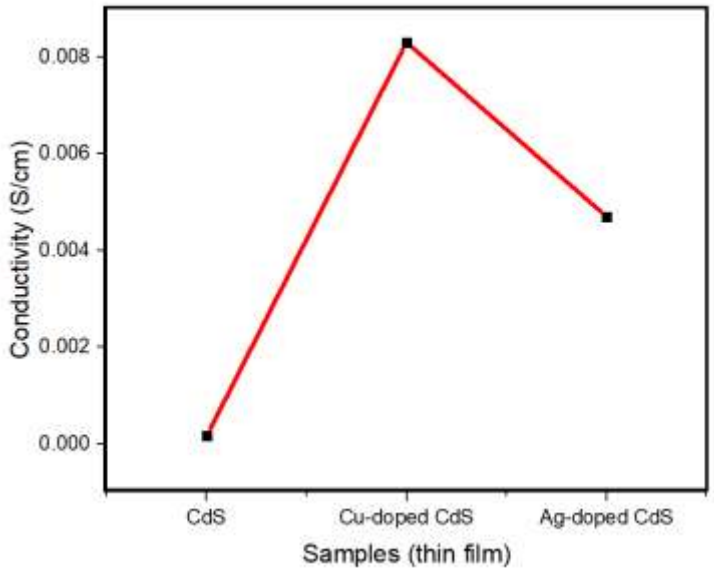


Figure 4. The electrical conductivity of CdS, Cu-doped CdS, and Ag-doped CdS thin films.

Figure 5 shows the EDX spectra of CdS, Cu-doped CdS, and Ag-doped CdS thin films synthesized via the chemical bath deposition (CBD) method. EDX analysis was carried out to confirm the elemental composition of the films and to verify the successful incorporation of dopant ions (Cu and Ag) into the CdS matrix.

The spectrum of the undoped CdS film displays characteristic peaks corresponding to cadmium (Cd) and sulfur (S), with prominent Cd L and Cd K peaks around 3.1 keV and 6.2 keV, and an S K peak near 2.3 keV. These peaks confirm the formation of stoichiometric CdS in the film.

In the Cu-doped CdS film, the EDX spectrum reveals the same Cd and S peaks as in the undoped film, along with an additional Cu K peak around 8.0 keV. The presence of this copper peak clearly confirms the successful incorporation of Cu ions into the CdS structure. Furthermore, the intensity of the Cd and S peaks remains relatively stable, suggesting that Cu has substituted into the lattice without significantly disrupting the stoichiometry.

Similarly, the spectrum of the Ag-doped CdS film shows Cd and S peaks along with an additional Ag L peak at approximately 3.0 keV. This verifies the incorporation of Ag into the CdS thin film. The Ag signal, along with consistent Cd and S signals, indicates that the doping occurred without the formation of secondary phases such as Ag_2S or metallic Ag, which is in agreement with the XRD results.

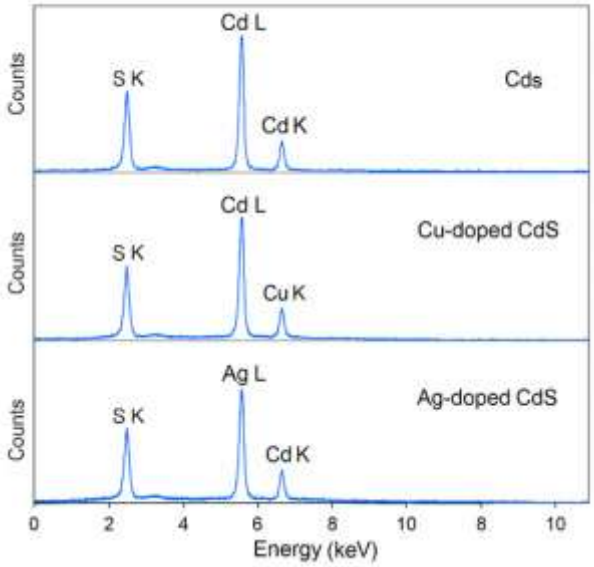


Figure 5. The EDX spectrum of CdS, Cu-doped CdS, and Ag-doped CdS thin films.

Conclusions

In this study, CdS thin films were successfully synthesized with Cu and Ag dopants using the chemical bath deposition method. The structural, optical, electrical, and compositional properties of the films were comprehensively analyzed. XRD results confirmed that all films retained the hexagonal crystal structure of CdS, with a slight reduction in crystallite size due to doping. SEM images showed improved surface uniformity and compaction in the doped samples. Film thickness increased slightly upon doping, from 325 nm for undoped CdS to 333 nm and 337 nm for Cu- and Ag-doped films, respectively. UV-Vis spectroscopy revealed a redshift in the absorption edge upon doping, indicating band gap narrowing from 2.36 eV (CdS) to 2.28 eV (Cu-doped) and 2.22 eV (Ag-doped). Tauc plot analysis supported these findings, highlighting the enhanced optical absorption in the visible range. Electrical measurements demonstrated that Cu doping significantly increased conductivity, from 1.6×10^{-4} S/cm (undoped) to 8.3×10^{-3} S/cm, with Ag doping resulting in 4.7×10^{-3} S/cm. These improvements are attributed to increased carrier concentration and improved film morphology. EDX spectra confirmed the successful incorporation of Cu and Ag into the CdS matrix without forming secondary phases.

Overall, the enhanced structural integrity, reduced band gap, and improved conductivity of Cu- and Ag-doped CdS thin films make them promising candidates for use as buffer layers in heterojunction solar cell applications.

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SYNTHESIS AND CHARACTERIZATION OF POMEGRANATE PEEL DERIVED SUPER ACTIVATED CARBON: TARGET ZERO WASTE

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ABSTRACT

Activated carbon (AC) is a commonly used catalyst support material and adsorbent due to its high specific surface area, porosity structure, and surface reactivity. Activated carbons with a specific surface area of more than 2000 $m^2.g^{-1}$ (super activated carbon) are becoming more popular. However, commercially available activated carbon is expensive and may not be economical. Therefore, preparing activated carbon from no-cost or locally sourced biomass materials from agricultural wastes such as coconut shells, olive stones, walnut shells, nut shells, citrus peels, vine wood, corncob, various fruit seeds, and barks is an attractive option. Thus, these wastes can be converted into economically valuable materials, and their environmental impact can also be reduced. For this purpose, in this study, super activated carbon was synthesized from pomegranate (*Punica Granatum L.*) peels via NaOH chemical activation and was characterized by FT-IR, XRD, SEM, and BET analysis.

The functional groups specific to AC were obtained in the FTIR spectrum. According to XRD analysis, the characteristic peaks of hexagonal crystalline activated carbon were observed. SEM micrographs showed that the external surfaces of AC were full of irregular pores. The BET specific surface area, total pore volume, and average pore width of AC were determined as 2309.0388 $m^2.\ g^{-1}$, 1.10367 $cm^3.g^{-1}$, and 2.23 nm, respectively. The N_2 adsorption/desorption isotherm of AC was confirmed to type I isotherm model according to the IUPAC classification.

Consequently, food waste materials with unique advantages, such as eco-friendly nature, availability, and low cost, are suitable precursors for preparing activated carbon. Moreover, the synthesized super activated carbon can be an efficient adsorbent for removing toxic pollutants from water supplies owing to its high surface area.

Keywords: Pomegranate peel, Super activated carbon, NaOH activation, Waste treatment, Characterization.

INTRODUCTION

Activated carbons are widely preferred adsorptive materials, especially in water treatment processes, environmental protection, and catalyst support, thanks to their highly developed specific surface area, porosity, and high stability properties (Saadi et al., 2022). The evolution of technology has led to an expansion in the range of applications for activated carbons, including their use in supercapacitors, electrodes, and gas storage. Therefore, super activated carbon is increasingly favorable due to its specific surface area, which exceeds 2000 m^2. g^{-1} to satisfy developed technology requirements (Li et al., 2017; Danish et al., 2018).

Currently, the production of commercial activated carbons involves the utilization of expensive and non-renewable feedstocks, including coal, petroleum coke, and precursors with high carbon content, such as wood, bituminous coal, anthracite, and peat. Consequently, traditional activated carbons are not cost-effective. Moreover, the regeneration of used activated carbon is a highly challenging process. As a result, significant efforts have been dedicated to preparing amorphous activated carbon from renewable sources, particularly lignocellulosic materials and agricultural by-products (Li et al., 2017; Gayathiri et al., 2022). It is reported various agricultural biomass sources such as fruit stones and nutshell (hazelnut shells, peanut hulls), palm oil shell waste, spent coffee ground, apricot stones, wheat straw, *Jatropha curcas* fruit shells, neem leaves, cassava peel, etc. were used to produce low-cost activated carbon (Danish et al., 2018).

The pomegranate fruit *(Punica granatum L.)* is a member of the Punicaceae family and has been cultivated since ancient times in the Mediterranean region, with a current global production of approximately 1 million tons (Saadi et al., 2022). The species is native to India, Malaysia, Iran, Turkey, and Africa. Turkey is a prominent producer of pomegranate, ranking among the top five countries in the world in terms of annual production, and ranking 4th with a yield of approximately 681,460 tons in 2022 (Polat et al., 2024). An important industry has grown up around the pomegranate. People consume it freshly or use it in many different ways in the kitchen, like as a garnish on food, in smoothies, and drinks like cocktails and wine (Saadi et al., 2022). These industries create a lot of lignocellulosic waste, which is mostly made of pomegranate peels. The peel of the pomegranate fruit constitutes approximately 40 – 50% of the total fruit weight (Khalo et al., 2023). Therefore, the synthesis of activated carbon from pomegranate peel could be viable to reuse and valorize this waste.

The objective of this study is synthesis and characterization of super activated carbon from pomegranate peels. For this purpose, pomegranate *(Punica Granatum L.)* peel derived super activated carbon was synthesized via the NaOH chemical activation method. The material was characterized by FT-IR, XRD, SEM, and BET analysis.

MATERIALS AND METHODS

All chemicals used were of analytical grade. Sodium hydroxide (NaOH) was purchased from the Merck company.

Preparation of pomegranate peels

The pomegranate fruit used in the study was obtained from local markets. After domestic consumption, the pomegranate peels were rinsed with tap water and cut into thin slices. Then, the peels were thoroughly cleaned with deionized water and dried in an oven at 60°C for 72 h. The dried pomegranate peels were ground into powder using a coffee grinder.

Synthesis of pomegranate peel derived super activated carbon

First, 25 g of pomegranate peel powder was pre-carbonized in a muffle furnace at 400°C for 2 hours. The NaOH solution was prepared in 50 mL of distilled water, with a weight ratio of 1:5 (w/w %) based on the amount of carbonized material for the NaOH activation step. The NaOH solution was then poured into the carbonized pomegranate peels, and the mixture was stirred at 450 rpm for 2 hours. Then, the mixture was dried in an oven at 130°C for 6 h. The dried material was taken to a muffle furnace and kept at 810°C for 2 h to ensure complete carbonization. The activated carbon was cooled and washed with distilled water for ≈ 10 days until the pH of the wash water became neutral. Then, it was dried in an oven at 70°C for 24 h (Esmaeili Bidhendi et al., 2020).

Characterization studies

The surface functional groups were determined by FT-IR analysis in the range of 400 – 4000 cm^{-1} using a Bruker brand FT-IR device. The crystal structure of the material was determined by XRD analysis using nickel-filtered Cu Kα radiation in a Rigaku Miniflex 600 brand device at 40 kV and 15 mA, 2θ=10°–90° conditions. The morphological structure of super activated carbon was determined by a TESCAN MIRA3 XMU model SEM device. The specific surface area, total pore volume, and average pore width of the pomegranate peel derived super activated carbon were determined with the nitrogen adsorption technique at 76.256 K using Micromeritics ASAP 2020V 3.00 G Brunauer-Emmett-Teller (BET) surface area analyzer. Before BET measurement, the activated carbon was degassed at 150°C under vacuum for 2 h.

RESULTS AND DISCUSSIONS

Characterization of pomegranate peel derived super activated carbon

FT-IR analysis

FT-IR analysis was performed to determine the surface functional groups in the structure of the synthesized super activated carbon, and the obtained FT-IR spectrum is presented in Figure 1.

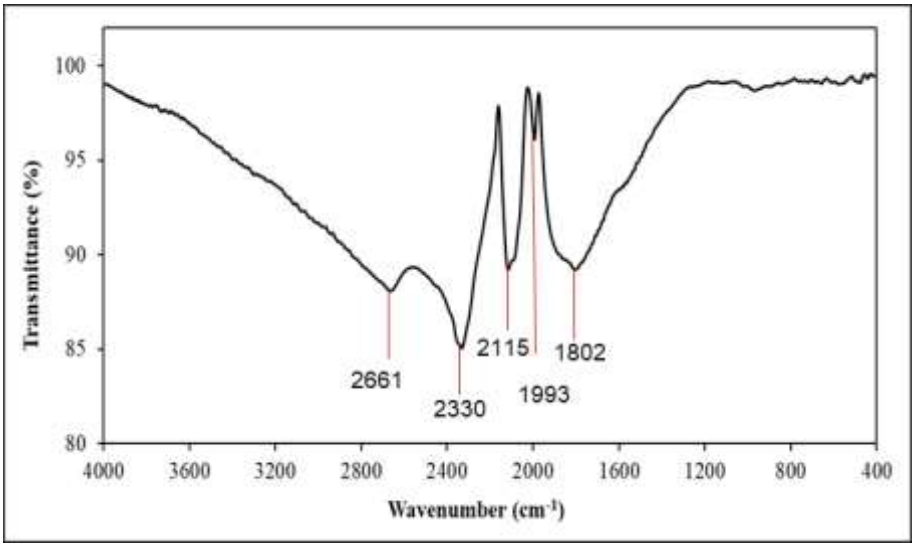


Figure 1. FT-IR spectrum of pomegranate peel derived super activated carbon

In this study, the pomegranate peel derived super activated carbon synthesized by NaOH activation was similar to the FT-IR spectrum of the super activated carbon prepared from gulfweed by KOH activation in the literature (Li et al., 2017). The presence of a band at 2661 cm^{-1} in the FT-IR spectrum suggests the potential presence of chemically bound metallic sodium within the pore structure, despite prolonged washing. The bands observed at 2330 cm^{-1} and 2115 cm^{-1} can be attributed to multivalent inorganic hydride or oxide components (Li et al., 2017). The vibration band observed at 1993 cm^{-1} is consistent with the methylcellulose peaks (Solmaz et al., 2023). The band at 1802 cm^{-1} is attributed to the C=O stretching vibration originating from carbonyl groups (Chen et al., 2014).

XRD analysis

The phase composition, the crystal structure, and the purity of the synthesized super activated carbon were determined by XRD analysis. The XRD pattern of pomegranate peel derived super activated carbon is presented in Figure 2.

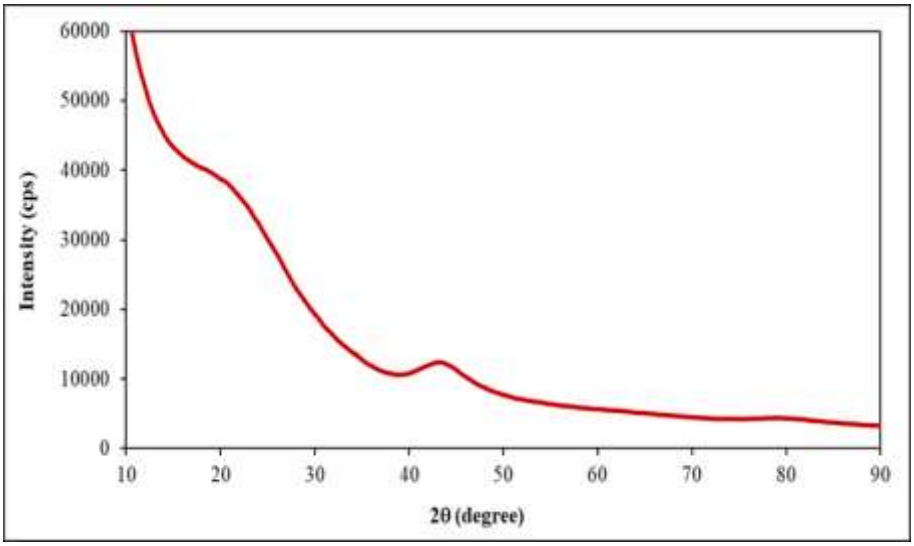


Figure 2. XRD pattern of pomegranate peel derived super activated carbon

As illustrated in Figure 2, the broad peak observed between $2\theta \approx 20° - 25°$ and the weak peak at $2\theta = 43°$ are attributed to the diffraction of turbostratic carbon (002) and the diffraction of graphitic type carbon with disordered or amorphous structure (001), respectively. These peaks are characteristic of hexagonal crystalline activated carbon (Sabaa et al., 2022).

SEM analysis

The surface physical morphology of the super activated carbon was observed through the SEM analysis. Figure 3 presents the SEM micrographs of pomegranate peel derived super activated carbon at different magnifications.

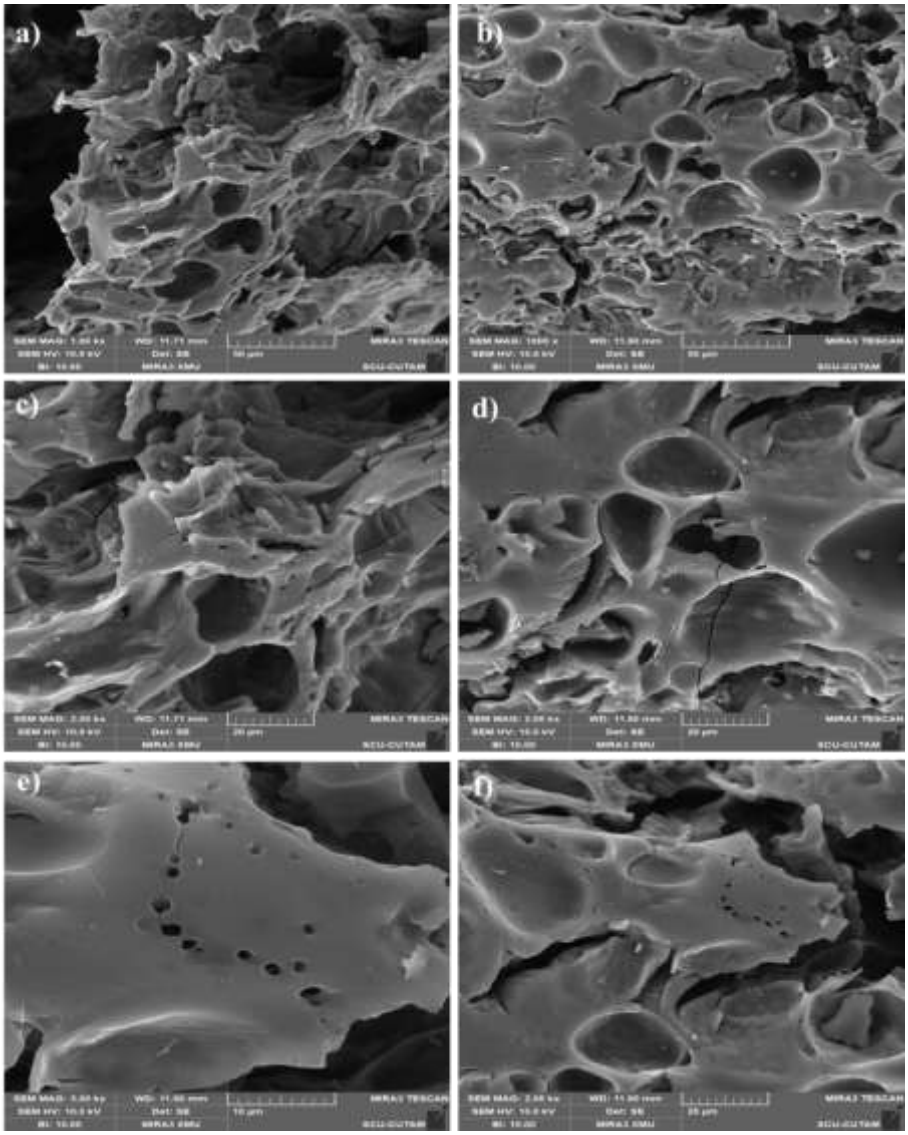


Figure 3. SEM images of activated carbon at different magnifications (a-b): 50µm-1kx, (c-d): 20µm-2kx, (e): 10µm-5kx, (f): 20µm-2kx

As illustrated in Figure 3, the external surfaces of the activated carbon are both porous and quite irregular. The distinct pore morphologies result from the interaction between the carbon atoms and NaOH and the impact of elevated temperatures during the activation process.

N_2 adsorption-desorption isotherms, and the BET specific surface area

Nitrogen adsorption at 77 K is a frequently utilized method to measure the porosity and surface areas of porous materials. This method is advantageous due to the comparatively smaller diameter of nitrogen molecules. It is the standard procedure to determine the porosity structure of carbon-based adsorbents. The adsorption isotherm is a key component of the analysis, providing critical insights into the pore structure of the adsorbent. This information includes the adsorption heat and the physical characteristics of the adsorbent (Chen et al., 2014). The classification of adsorption isotherms established by the International Union of Pure and Applied Chemistry (IUPAC) is illustrated in Figure 4. The IUPAC classification identifies six

types of isotherms: microporous (type I), nonporous or macroporous (types II, III, and VI), and mesoporous (types IV and V) (ALOthman 2012).

The N_2 adsorption-desorption isotherms of pomegranate peel derived super activated carbon are presented in Figure 5. According to Figure 5, the N_2 adsorption-desorption isotherm of pomegranate peel derived super activated carbon conforms to the type I isotherm model (Figure 4), which is frequently observed in microporous solids such as activated carbon and zeolite according to the IUPAC classification. The type I isotherm is defined by the presence of microporous solids and is concave concerning the P/P^o axis. As the $P/P^o \rightarrow 1$, the uptake value approaches a limiting value. The region of significant inclination at low P/P^o is attributable to the saturation of exceedingly confined pores. The constrained uptake is contingent on the accessible micropore volume, as opposed to the internal surface area (Chen et al., 2014).

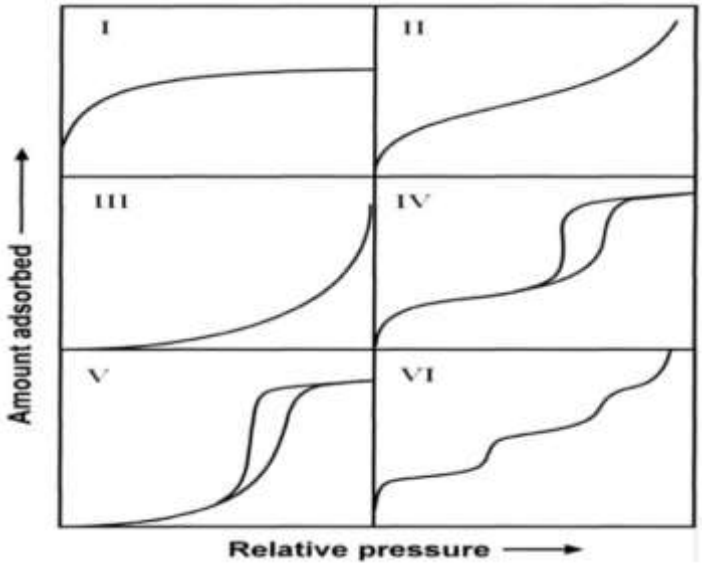


Figure 4. The IUPAC classification of adsorption isotherms shows the adsorption and desorption pathways (ALOthman 2012).

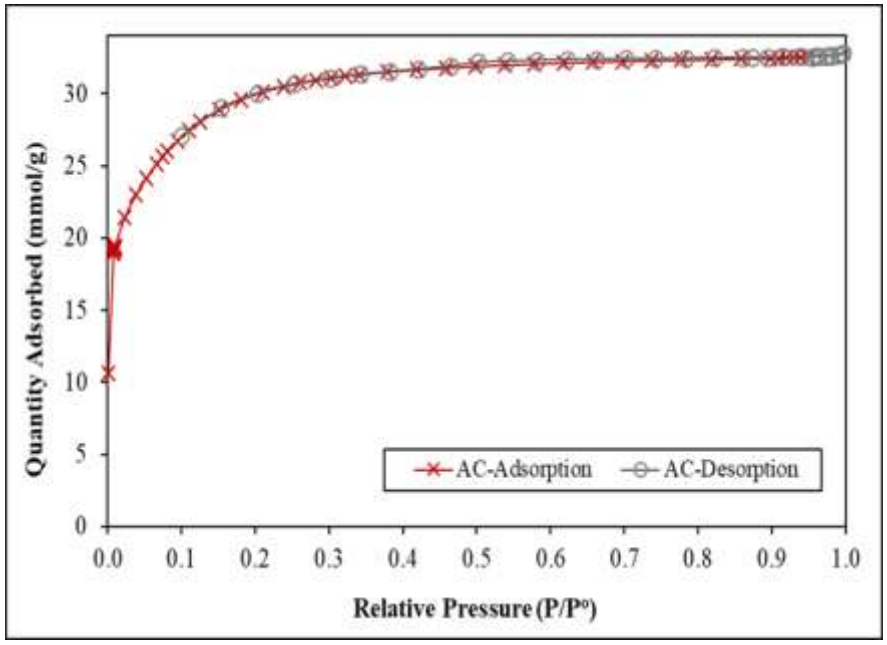


Figure 5. The N_2 adsorption-desorption isotherms of pomegranate peel derived super activated carbon

The BET specific surface area (S_{BET}), total pore volume (V), and adsorption average pore width (W_d: $4V/S_{BET}$) of the prepared super activated carbon were obtained by applying the BET equation to N_2 adsorption isotherm at 77 K, are presented in Table 1, also a number of the studies for the biomass-derived activated carbons in the literature are also listed in Table 1. As seen in Table 1, the specific surface area (S_{BET}), total pore volume (V), and adsorption average pore width (W_d) of the super activated carbon prepared from pomegranate peel were determined as 2309.04 ± 23.19 $m^2 . g^{-1}$, 1.10367 $cm^3 . g^{-1}$, and 2.23 nm, respectively. The IUPAC pore dimension classifications group pores into micropores ($d < 2$ nm), mesopores ($d = 2–50$ nm), and macropores ($d > 50$ nm) (Chen et al., 2014). Accordingly, the synthesized super activated carbon has a mesoporous structure according to the type I adsorption isotherm model.

The surface area and pore properties of the super activated carbon obtained in this study resemble those of similar activated carbons reported in the literature. However, the specific surface area and pore properties of the synthesized activated carbons can vary depending on the biomass utilized, the activation agent, the activation temperature, time, the impregnation ratio of activation agent, pyrolysis conditions, or the carbonization temperature and time.

Table 1. The surface area and pore properties of super activated carbon synthesized in this study, and some of the studies for the biomass-derived activated carbons in the literature.

Biomass	**Activation Method**	**BET specific surface area ($m^2 g^{-1}$)**	**Total pore volume ($cm^3 g^{-1}$)**	**Pore width (nm)**	**Reference**
Pomegranate peel	NaOH	2309.04 ± 23.19	1.10367	2.23	**This study**
Corncob	KOH	3530	1.94	-	Zhang et al., 2013
Argan shells	KOH/melamine	2132	2.18	-	Elmouwahidi et al., 2012
Sunflower seed shell	KOH	2585	1.41	2.1	Li et al., 2011
Gulfweed	KOH	3362	3.08	-	Li et al., 2017
Heterophyllus peel	H_3PO_4	1585	0.965	10	Ramalingam et al., 2020
Cow dung	H_3PO_4	2450	-	-	Ramalingam et al., 2020
Lemon pomace	H_3PO_4	1378.57 ± 1.506	-	1.11	Oruç et al., 2019
Orange peel	KOH	2521	1.30	1.04	Ranaweera et al., 2017
Pomegranate peel	NaOH	694	-	3.01	Esmaeili Bidhendi et al., 2020
Pomegranate peel	K_2CO_3	1860	0.879	-	Saadi et al., 2022
Pomegranate peel	KOH	2141	1.28	-	Ouzzine et al., 2021

CONCLUSIONS

In this study, super activated carbon with a high specific surface area and large pore volume was synthesized through an efficient biosynthesis method using pomegranate (*Punica Granatum L.*) peels. The characterization studies (FT-IR, XRD, SEM, and BET) showed that the super-activated carbon was prepared successfully. Accordingly, the reuse of

food waste by-products not only prevents environmental pollution arising from these wastes but also reduces carbon emissions. Furthermore, this approach offers the potential for the transformation of locally abundant industrial and domestic wastes into new and cost-effective valuable materials. Moreover, the synthesized super-activated carbon can be utilized for many areas such as wastewater treatment, supercapacitor, and CO_2 adsorption applications owing to its high surface area.

ACKNOWLEDGMENTS

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PHYTOREMEDIATION OF TEXTILE DYE EFFLUENTS USING AQUATIC PLANTS

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ABSTRACT

Environmental pollution is a significant problem that threatens the health of living beings and the balance of the ecosystem. This pollution is caused by human activities as well as natural processes and is classified into three main categories: physical, chemical, and biological. Especially dyes used in industries such as the textile sector have serious negative effects on the environment. These substances, which have toxic, carcinogenic, and mutagenic properties, disrupt the balance of nature and pose a threat to both humans and other living things. Physical, chemical, and biological methods are used to remove dyes from the environment. Phytoremediation is one of the environmentally friendly and sustainable biological methods that aim to clean pollutants through plants. Although it has advantages such as being economical, not requiring energy, and not harming environmental resources, the application of this method can take a long time, and there may be limitations in reaching deep underground pollutants. When suitable conditions are provided, phytoremediation offers an effective solution in combating environmental pollution and contributes to the sustainability of the ecosystem. Natural adsorption processes are an economical and environmentally friendly solution for removing these harmful substances. By utilizing the adsorption properties of plants such as *Spirodela polyrrhiza, Ceratophyllum demersum L., Eichhornia crassipes, Pistia stratiotes,* and *Lemna minor,* environmental sustainability is targeted, and fewer side effects are provided compared to chemical methods. These studies aim to create a model for both ecosystem protection and future environmental solutions.

Keywords: Phytoremediation, Water treatment, Adsorption, Textile dyestuffs, Aquatic plants.

SU BİTKİLERİ KULLANILARAK TEKSTİL BOYAR MADDELERİNİN FİTOREMEDİASYONU

ÖZET

Çevre kirliliği, canlıların sağlığını ve ekosistemin dengesini tehdit eden önemli bir sorundur. Bu kirlilik, doğal süreçlerin yanı sıra insan faaliyetlerinden kaynaklanmakta ve fiziksel, kimyasal ve biyolojik olmak üzere üç ana kategoride sınıflandırılmaktadır. Özellikle tekstil sektörü gibi endüstrilerde kullanılan boyar maddeler, çevre üzerinde ciddi olumsuz etkilere sahiptir. Toksik, kanserojen ve mutajenik özelliklere sahip bu maddeler, doğanın dengesini bozarken hem insanlar hem de diğer canlılar için tehdit oluşturur.

Boyar maddelerin sucul ortamdan giderilmesi amacıyla fiziksel, kimyasal ve biyolojik yöntemler kullanılmaktadır. Fitoremediasyon, kirleticileri; bitkiler aracılığıyla bertaraf etmeyi amaçlayan çevre dostu ve sürdürülebilir biyolojik yöntemlerden biridir. Ekonomik olması, enerji gerektirmemesi ve çevresel kaynaklara zarar vermemesi gibi avantajları olmasına rağmen bu yöntemin uygulanması uzun zaman alabilir ve derin yeraltı kirleticilerine ulaşmada sınırlamalarla karşılaşılabilir. Uygun koşullar sağlandığında fitoremediasyon, çevre kirliliği ile mücadelede etkili bir çözüm sunar ve ekosistemin sürdürülebilirliğine katkıda bulunur. Doğal adsorpsiyon süreçleri, bu zararlı maddelerin giderilmesinde ekonomik ve çevre dostu bir çözümdür. *Spirodela polyrrhiza, Ceratophyllum demersum L., Eichhornia crassipes, Pistia stratiotes* ve *Lemna minor* gibi su bitkilerinin adsorplayıcı özelliklerinden faydalanılarak çevresel sürdürülebilirlik hedeflenmekte, kimyasal yöntemlere kıyasla daha az yan etki sağlanmaktadır. Bu çalışmalar hem ekosistemin korunması hem de gelecekteki çevresel çözümler için bir model oluşturmayı amaçlamaktadır.

Anahtar Kelimeler: Fitoremediasyon, Su arıtımı, Adsorpsiyon, Tekstil boyar maddeleri, Su bitkileri

1. Giriş

Endüstrideki hızlı değişim ve bu değişime bağlı olarak üretilen ürünler, doğal kaynakların hızla tükenmesine, atık miktarının artmasıyla çevrenin kirlenmesine neden olmaktadır. Özellikle tekstil sektöründe renkli ürünler elde etmek amacıyla yaygın olarak kullanılan boyar madde ve pigmentler, üretim sonrası toksik ve kanserojen organik maddeler içeren atık suların oluşmasına yol açmaktadır. Bu zararlı maddelerin çevreye yayılmadan önce atık sulardan giderilmesi, gerekmektedir (Süzen, 2015). Boyar madde atıklarının çevreye zararları oldukça ciddi ve çok yönlüdür. Üretim sonrası belirli bir deşarj seviyesine indirilmeden su kaynaklarına bırakılan boyar maddeler suyun rengini değiştirerek ışık geçirgenliğini azaltır, toksik ve kanserojen moleküller içerdiğinden su canlılarının yaşamını olumsuz etkiler. Ayrıca bu organik maddeler toprağa sızarak toprak yapısının bozulmasına ve tarımsal verimin düşmesine neden olabilir. Özellikle içme suyuna karıştığında insan sağlığı için büyük risk oluşturan boyar maddelerin canlı sağlığı üzerinde de olumsuz etkileri vardır. Bu maddeler canlılarda genetik mutasyonlara, hormonal bozukluklara ve kansere yol açabilir (Özdemir Koçak vd., 2024).

Boyar madde içeren atık suların gideriminde fiziksel, kimyasal ve biyolojik yöntemler kullanılır. Her yöntemin kendine özgü avantajları ve dezavantajları bulunmaktadır. Atık su arıtımında kullanılan yaygın yöntemler ve avantaj ve dezavantajları Tablo 1'de sunulmuştur.

Tablo 1. Atık su arıtımında kullanılan yaygın yöntemler (Namal, 2017).

Yöntem	Kullanılan reaktif/kaynak	Kategori	Avantaj	Dezavantaj
Adsorpsiyon	Aktif karbon, zeolit, kil	Fiziksel/ Kimyasal	Yüksek verim, geniş yüzey alanı	Yüksek maliyet, doygunluk sorunu
Membran Filtrasyonu	Ultrafiltrasyon, nanofiltrasyon, ters ozmoz	Fiziksel	Yüksek ayırma kapasitesi, kompakt sistem	Yüksek enerji tüketimi, membran kirlenmesi
Koagülasyon-Flokülasyon	Kimyasal çöktürücüler	Fiziksel	Kolay uygulanabilirlik, düşük maliyet	Kimyasal kullanımı, çamur oluşumu
Oksidasyon	Ozon, hidrojen peroksit, Fenton reaktifi	Kimyasal	Etkili renk giderimi, geniş uygulama alanı	Yüksek maliyet, yan ürün oluşumu
Fotokatalitik Yöntemler	UV ışığı ve katalizör (örneğin TiO_2)	Kimyasal	Yüksek etkinlik, düşük enerji tüketimi	Katalizör maliyeti, uzun işlem süresi
Elektrokimyasal Arıtma	Elektrik akımı	Kimyasal	Yüksek verim, kimyasal kullanımı yok	Yüksek enerji tüketimi, elektrot aşınması
Aktif çamur Prosesi	Mikroorganizmalar	Biyolojik	Düşük maliyet, doğal süreç	Uzun işlem süresi, hassas denge
Biyoreaktörler	Özelleştirilmiş mikroorganizmalar	Biyolojik	Yüksek verim, kompakt sistem	Yüksek maliyet, karmaşık işletim
Fitoremediasyon	Algler , su bitkileri ve mantar türleri	Biyolojik	Doğal süreç, düşük maliyet	Uzun işlem süresi, sınırlı etkinlik

Bu yöntemlerden biri olan fitoremediasyon, düşük maliyetli ve çevre dostu olması nedeniyle boyar madde içeren atık suların arıtımında tercih edilen bir yaklaşımdır. Bitkiler, kendi doğal ortamlarında adsorbent görevi görerek kökleri aracılığıyla boyar madde moleküllerini tutarak sucul ortamdan ayırır.

2. Fitoremediasyon: Bitkilerle Atık Su Arıtımı ve Çevresel Sürdürülebilirlik

Fitoremediasyon, bitkilerin kirleticileri doğal yollarla arıtma yeteneğine dayanan bir yöntemdir. Kelime kökeni Latince olup, "phyto" (bitki) ve "remediation" (iyileştirme) kavramlarının birleşiminden türetilmiştir. Çevresel sürdürülebilirlik açısından önemli bir teknik olan fitoremediasyon süreci, bitkisel arıtım, yeşil ıslah veya ekolojik iyileştirme gibi farklı isimlerle de anılmaktadır (Tiryaki ve Potur, 2017).

Bu süreçte adsorpsiyon, kirleticilerin bitki yüzeylerine veya kök sistemlerine bağlanarak sudan veya topraktan uzaklaştırılmasını sağlayan temel mekanizmadır. Özellikle ağır metaller, pestisitler ve organik kirleticiler, bitkilerin kökleri, yaprak yüzeyleri veya hücresel yapıları tarafından adsorbe edilerek ortamdan elimine edilir. Adsorpsiyon, kirleticilerin doğrudan suya veya toprağa karışmasını önleyerek ekosistemin korunmasına katkı sağlar. Bu mekanizma sayesinde bitkiler, kirleticileri bünyelerine alarak su ve toprak kalitesini iyileştirmede etkili rol oynar. Bu yöntem, özellikle düşük maliyetli ve çevre dostu bir alternatif sunması nedeniyle dikkat çekmektedir (Hamutoğlu vd., 2012).

Bu süreç, kirleticinin türüne ve ortam koşullarına bağlı olarak farklı mekanizmalarla gerçekleşir. Örneğin, bazı bitkiler kirleticileri kökleriyle adsorbe edip sudan uzaklaştırırken (rizofiltrasyon), bazıları kirleticileri bünyesine alıp biriktirerek ortamdan temizlenmesini sağlar (fitoekstraksiyon). Mikroorganizmalarla etkileşim halinde gerçekleşen süreçlerde kirleticiler parçalanarak etkisiz hale getirilir (rizodegradasyon, fitodegradasyon), ya da bitkiler belirli kirleticileri bünyelerine aldıktan sonra yaprakları aracılığıyla atmosfere salar (fitovolatilizasyon). Ayrıca, bazı bitkiler kirleticilerin hareketliliğini azaltarak onların yayılmasını engeller ve stabil hale getirir (fitostabilizasyon) (Hamutoğlu vd., 2012).

3. Fitoremediasyon Yönteminin Avantaj ve Dezavantajları

Fitoremediasyon, çevresel kirleticilerin bitkiler aracılığıyla giderilmesini sağlayan sürdürülebilir bir yöntemdir. Ancak, bu yöntemin uygulanabilirliği avantajları ve bazı sınırlamalarla birlikte değerlendirilmelidir.

Fitoremediasyon yönteminin avantajları aşağıdaki sunulmuştur:

• Ekonomik ve düşük enerji gereksinimi: Geleneksel fizikokimyasal arıtma yöntemlerine kıyasla, fitoremediasyon daha az maliyetli olup ek enerji girdisi gerektirmez. Bitkiler doğal süreçler aracılığıyla kirleticileri uzaklaştırdığı için işletme maliyetleri düşüktür.

• Yerinde arıtım imkânı: Kirlenmiş alanın taşınmasına gerek kalmadan, kirleticilerin bulunduğu yerde giderilmesini sağlar. Bu, ek lojistik maliyetleri ortadan kaldırarak süreci daha verimli hale getirir (Aybar vd., 2015).

• Tekli ve ikili karışımların giderimi: Fitoremediasyon, yalnızca tek bir kirleticiye odaklanmak yerine, ağır metaller, organik bileşikler ve diğer kirleticileri aynı anda temizleyebilir.

• Ekosistem dostu ve sürdürülebilir: Bitkiler, kirleticileri absorbe ederek veya metabolize ederek çevreye zarar vermeden doğal bir arıtma süreci sunar. Bu yöntem, ekolojik dengeyi koruyarak uzun vadeli çevresel iyileştirme sağlar (Hamutoğlu vd., 2012).

Fitoremediasyon yönteminin dezavantajları ise aşağıdaki gibi sıralanabilir:

• Bazı bitkilerin toksik bileşiklere karşı hassasiyeti: Hiperakümülatör bitkiler belirli kirleticilere karşı dayanıklı olsa da yüksek toksisiteye sahip bileşikler bitkilerin büyümesini ve metabolik süreçlerini olumsuz etkileyebilir. Bu nedenle, uygun bitki türlerinin seçimi kritik öneme sahiptir.

• Toprak ve su koşullarına bağımlılık: Fitoremediasyonun başarısı, kullanılan bitkilerin edafik ve biyotik faktörlere uyum sağlamasına bağlıdır. Uygun olmayan çevresel koşullar, bitkilerin kirleticileri etkili şekilde absorbe etmesini zorlaştırabilir (Aybar vd., 2015).

• Arıtma süresinin uzunluğu: Fitoremediasyon, fizikokimyasal yöntemlere göre daha uzun sürede sonuç verir. Kirleticilerin bitkiler tarafından alınması ve metabolize edilmesi zaman gerektirdiğinden, hızlı arıtma gerektiren durumlarda yeterli olmayabilir (Hamutoğlu vd., 2012).

4. Fitoremediasyon Yönteminde Kullanılan Bazı Bitkiler ve Literatür Çalışmalarından Örnekler

Fitoremediasyon yönteminde genellikle hiperakümülatör bitkiler kullanılmaktadır. Bu bitkiler seçici özellik göstererek farklı türdeki kirleticileri adsorplayarak atık suların arıtımında etkili olabilirler.

Süreli yayınlar incelendiğinde, su bitkilerinin boyar madde, farmasötik bileşik ve ağır metal iyonu gibi kirleticilerin gideriminde kullanımına yönelik sınırlı sayıda çalışmaya rastlanmıştır.

Keskinkan tarafından 2006 yılında yürütülen bir çalışmada; *Ceratophyllum demersum* ve *Myriophyllum spicatum* su bitkilerinin Bazik Mavi 41 (Basic Blue 41, BB 41) azo boyarmaddesinin gideriminde adsorbent olarak kullanımı incelenmiştir. Çalışma sonuçlara göre, BB 41 boyar maddesinin adsorpsiyonunda, *Myriophyllum spicatum* ile yürütülen çalışmalarda maksimum adsorpsiyon kapasitesi 64,9 mg/g; *Ceratophyllum demersum*'un adsorbent olarak kullanıldığı çalışmalarda ise maksimum adsorpsiyon kapasitesi 50,0 mg/g olarak belirlenmiştir. Sonuç olarak, bu iki su bitkisinin fitoremediasyon ile boyar madde gideriminde efektif birer adsorbent olarak kullanılabileceği görülmüştür (Keskinkan, 2006).

Aasim ve Nadeem tarafından 2024 yılında yapılan bir araştırmada, *Ceratophyllum demersum*'un sucul ortamda bulunabilen kirleticileri adsorplama potansiyeli incelenmiş, bu bitkinin fitoremediasyon süreçlerindeki etkisini ortaya konulmuştur. Özellikle kadmiyum (Cd) gibi ağır metalleri sudan adsorplayabilme özelliği değerlendirilmiş ve biyokonsantrasyon faktörü (BCF) ile metal giderme yüzdesi analiz edilmiştir. Sonuçlar, *Ceratophyllum demersum*'un yüksek adsorpsiyon kapasitesi sayesinde etkili bir adsorbent olabileceğini göstermiştir. Çalışma ayrıca, yapay zekâ tabanlı modellemeler ile bitkinin kirletici giderim süreçlerinin tahmin edilmesine katkı sağlamıştır. (Aasim & Nadeem, 2024).

Ewadh, 2020 yılında yaptığı bir çalışmada, *Ceratophyllum demersum*'un metilen mavisi boyar maddesinin adsorpsiyon ile giderimini araştırmıştır. *Ceratophyllum demersum* ile Metilen Mavisi adsorpsiyonunda %96 oranında boyarmadde giderimi elde edildiği belirtilmiştir. Adsorpsiyon mekanizmaları açısından, bitkinin kirleticiyi hücre duvarı ve yüzey yapılarına bağlayarak sudan adsorpladığı vurgulanmıştır. Bu çalışma, boyar maddelerin fitoremediasyonunda bitkilerin kullanımının düşük maliyetli ve çevre dostu bir çözüm olabileceğini göstermiştir (Ewadh, 2020).

Konuk 2008 yılında yürüttüğü çalışmada, su sümbülü 'nün *(Eichhornia crassipes)* Malahit Yeşili, Metilen Mavisi ve Reaktif Sarı 145 boyar maddelerinin adsorpsiyon ile giderimini araştırmıştır. Çalışma sonucunda; su sümbülünün endüstriyel atık sulardaki katyonik boyarmaddelerin giderilmesinde etkili bir adsorbent olarak kullanılabileceği ortaya konulmuştur. Bitkinin geniş yüzey alanı ve biyolojik yapısı sayesinde su kirliliğini azaltmada doğal ve sürdürülebilir bir çözüm sunduğu vurgulanmıştır (Konuk, 2008).

Ayrıca, yapılan bazı çalışmalarda, bitkilerin farklı ağır metalleri de adsorplayabildiği görülmüştür. Boyar maddelerin ve ağır metallerin su bitkileri ile giderimine yönelik literatürde yer alan bazı çalışmalar Tablo 2'de sunulmuştur.

Tablo 2. Boyar maddelerin ve ağır metallerin su bitkileri ile giderimine yönelik literatürde yer alan bazı çalışmalara örnekler

Bitki	Yöntem	Hedef Kirletici	Verim	Kaynak
Ceratophyllum demersum	Adsorpsiyon, Fitoremediasyon	Metilen Mavisi	%96 oranında boyar madde giderimi	(Ewadh, 2020)
Myriophyllum spicatum	Adsorpsiyon	Bazik Mavi 41	Maksimum adsorpsiyon kapasitesi: 64,9 mg/g	(Keskinkan, 2006)
Eichhornia crassipes	Adsorpsiyon, fitoremediasyon	Malahit Yeşili, Metilen Mavisi	pH 9-10 arasında yüksek adsorpsiyon kapasitesi	(Konuk, 2008)
Ceratophyllum demersum	Fitoremediasyon	Kadmiyum (Cd)	Adsorbent özelliği gösterme	(Aasim & Nadeem, 2024)
Eichhornia crassipes	Adsorpsiyon	Krom (Cr)	Krom metaline seçiciliği yüksek	(Ubale & Ahuja, 2024)

5. Sonuç ve Öneriler

Fitoremediasyon, tekstil boyar maddelerinin alıcı su ortamından giderilmesinde çevre dostu ve sürdürülebilir bir alternatif sunmaktadır. Ancak yöntemin etkinliği, seçilen bitki türüne, boyar maddeye, çevresel koşullara ve uygulanan stratejilere bağlı olarak değişmektedir. Daha verimli bir arıtma süreci için uygun bitkilerin belirlenmesi büyük önem taşımaktadır. Çünkü, sürecin seçici özellik göstermesi nedeniyle her su bitkisi, her kirletici maddeyi adsorplama özelliği göstermemektedir.

Fitoremediasyonun daha etkin hale getirilmesi için fizikokimyasal arıtma teknikleriyle entegre edilmesi önerilmektedir. Örneğin, koagülasyon gibi yöntemlerle desteklenen sistemler, arıtma sürecinin verimini artırabilir. Diğer yandan, bitki kök bölgesinde bulunan mikroorganizmalar

kirleticilerin biyolojik olarak parçalanmasını destekleyebilir. Bu nedenle, bitki-mikroorganizma etkileşiminin artırılmasıyla fitoremediasyon verimi artırılabilir. Çevresel faktörlerin iyileştirilmesi de süreç için önemli bir unsurdur. Su kültürü ortamında yetiştirilen hiperakümülatör bitkiler, boyar maddelerin gideriminde kullanılabilir. Bitkilerin büyüme hızını artırmak amacıyla uygun pH, sıcaklık ve besin içerikleri sağlanmalıdır.

Bu adımların doğru şekilde uygulanması, fitoremediasyonun tekstil boyar maddelerinin gideriminde daha etkili bir çözüm haline gelmesini sağlayacaktır.

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EXPLORING THE COGNITIVE STRUCTURES OF SCIENCE FACULTY BIOLOGY STUDENTS ON CLEAN WATER AND SANITATION

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ABSTRACT

In biology departments of science faculties, education is provided on subjects such as living beings, nature and environment. Therefore, revealing the cognitive structures of students studying in this department about clean water and sanitation is essential in order to rapidly eliminate false information and lack of knowledge before starting their professional lives. Based on this, this study aimed to examine the cognitive structures of biology department students of science faculty about clean water and sanitation. The survey model was used in the study. Word association test was used as a data collection tool in the study. The sample of the study consists of ??? students studying in biology department of science faculty. In order to determine the results of the word association test, the answer words given to the key concepts of "Clean water" and "Sanitation" were examined. The answer words given for the key concept were written one by one and a frequency table was created. During the data analysis, the answer words given by the students to the key concept were used and the analyses were performed by two different raters in order to ensure the consistency of the data. Content analysis was performed on the relevant data to obtain common themes for each response. As a result, the most evocative theme for the concept of clean water was determined as life, while the least used theme was determined as water purification. Scientific inaccuracies include the views that clean water can only be obtained by boiling or that transparency is the only indicator of cleanliness. The most commonly used words for the concept of sanitation are: water, hygiene and health. Scientific inaccuracies include the views that sanitation can only be done in facilities or that it is a directly biological concept.

Keywords: Clean water, sanitation, word association test

Introduction

When you consider that three-quarters of the world is covered with water, that approximately 50-80% of the body weight of animals and 60% of an average adult human is water, it becomes easier to understand the importance of water for living things. However, the water on our planet is not as much as it is thought. Approximately 97.5% of the water on the planet consists of salt water. Drinking water is only 2.5%. 79% of this low amount of drinking water is hidden in glaciers and 20% underground. The part that we can easily reach to meet our needs is only 1% of the total drinking water. This part is renewed thanks to precipitation. Water is constantly polluted when used. When we do not recycle the polluted water, most of this water pollutes the areas it passes through and ends up in the oceans. Not the total amount of water, but the amount of drinkable water decreases in this way. And as a result of all this, an unwanted water shortage begins. Water scarcity affects more than 40% of humanity. More and more countries are experiencing water stress every day, and it is estimated that at least a quarter of the world's population will experience recurrent water deprivation by 2050 (WHO & UNICEF, 2019).

Although our country is very rich in terms of water resources, the rate of water pollution is also quite high. Water pollution is an important problem that directly affects the environment (MEB, 2012a; MEB, 2012b; MEB, 2014). Any change caused by water pollution, which is a sub-parameter of environmental pollution, also affects environmental pollution. Environmental pollution affects water the most among natural resources and causes water pollution (Menteşe, 2017). In order to protect and ensure the continuity of water resources that give life to everything around us, water pollution should be emphasized (Yılmaz & Yanarateş, 2020).

In general, water is used for irrigation of agricultural areas, meeting industrial needs and general purposes in homes. In recent years, due to changes in lifestyle and food habits, an increase in water consumption per person has been observed (Söylemez, Coşkun & Ardor, 2014). Despite the decreasing usable water potential, the fact that the world population needs more water every day has caused an increase in national and global sensitivity regarding water resources. Chemical fertilizers, agricultural pesticides, sewage, animal waste, toxic substances, solid and liquid wastes used to increase field yields are the main causes of water pollution. Although people themselves have caused all these negative activities, the water they need to sustain their lives must be delivered to them in a clean and healthy way. To ensure this, water must be purified from harmful factors and microorganisms that can cause diseases. In addition, appropriate measures must be taken to prevent used water from harming people and other living things and from polluting clean water resources.

On a global scale, approximately 80% of all industrial and human wastewater is released into the environment without pretreatment, with harmful effects on human health and ecosystems (Elerman, Yazıcı & Gültekin, 2022). This rate is much higher in underdeveloped countries where wastewater treatment facilities and sanitation are quite lacking (UNWWD Report, 2021). As of 2020, the difference between high-income and low-income countries in terms of access to international clean water is sharp. While the rich countries of the North generally have sufficient water reserves, it is seen that water shortages are experienced more in southern countries (Figure 1). Therefore, it is clearly seen today that water services should be considered together with sanitation (Çolakoğlu, 2011). Sanitation is the establishment of healthy cleaning and hygienic conditions and ensuring their continuity (Bulduk, 2003). Seafood products are products that can spoil quickly when the necessary hygiene, sanitation and storage conditions are not applied. For this reason, if the necessary conditions are not met, chemical and microbiological changes are observed in the product, which can lead to food poisoning. In order to prevent such problems, it will be possible to fulfill the hygiene, sanitation and protection

conditions of the fishery products from the time they are caught to the table. The fact that sanitation is a right and that it is addressed with water in terms of international water law is quite new. It is thought that by defining the right to sanitation, which means that every individual has access to adequate, safe and accessible sanitation where physical safety can be ensured, diseases such as cholera, malaria and dysentery, which are transmitted through water, can be prevented (Çolakoğlu, 2011).

When we look at the data on the issues discussed in this context, according to the report published jointly by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) in 2019, it is stated that nearly 2.2 billion people in the world do not have access to clean water when needed, and 4.2 billion people do not have access to sanitation facilities (UNICEF and WHO, 2019). In relation to this, the United Nations Development Program (UNDP) also emphasizes that 41 countries experienced water shortages in 2011 and that renewable water resources are on the verge of depletion in 10 of these.

Considering the suggestions about clean water and sanitation, it is obvious that individuals need to be conscious. At this point in terms of water usage and drinking water resources in the world; Are individuals not aware of the limitedness of water resources? Are individuals not conscious water consumers? Do individuals have knowledge about issues such as water transformation, cleaning, purification? Do they know the concepts of sanitation, cleaning and hygiene? Questions such as these come to mind. The answer to all these questions depends on how individuals structure these concepts in their minds. In learning a concept, the individual focuses on the structure, content or differences of the information they acquire. Therefore, knowing the individual's prior knowledge and structuring this information correctly and establishing meaningful connections with new information will ensure that the concept is taught correctly (Kurt & Ekici, 2013). Concept learning is a formation that is completed by becoming aware of the existing concepts in the mind and structuring a new scientific concept in the mind (Tsai & Huang, 2002). When there are incorrect or incomplete structures in the conceptual structures in the minds of students, students come to the classroom with alternative concepts that are far from scientific aspects. These concepts can negatively affect students when they want to learn a new concept (Mintzes, Wandersee, & Novak, 2001; Palmer, 2001). For this reason, knowing the student's prior knowledge is considered very important in determining the cognitive structure (Tsai & Huang, 2002; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). Gilbert, Boulter, and Rutherford (1998) emphasize that it is very difficult to explain the cognitive structures of individuals, but revealing their thoughts about key concepts is very important in this regard and these key concepts reveal the cognitive structures of individuals regarding the main concept. Especially during the conceptual change process, revealing alternative concepts that exist in students' cognitive structures is important for them to achieve meaningful learning (Kurt & Ekici, 2013). Revealing the cognitive structures of individuals about clean water and sanitation is also important in terms of teaching and understanding concepts related to the environment and water. In the literature, there are studies on the subject: the views of prospective teachers on conscious water consumption, the knowledge of prospective science teachers about water and water pollution, the conceptual understanding levels of 7th grade secondary school students on water pollution, the metaphorical perceptions of prospective teachers on the concept of water pollution, the increase in water awareness of kindergarten students, and the perceptions of university students on water and water pollution (Alaş, Tunç, Kışoğlu & Gürbüz, 2009; Kıryak, 2013; Köseoğlu, 2017; Kriper, 2014; Ursavaş & Aytar, 2018; Yılmaz & Yanarateş, 2020). When the relevant studies are examined, it is seen that the concept of water is mostly addressed in terms of water pollution and information is collected through surveys or opinions. No study has been found in which individuals' cognitive

structures about water and water-related concepts are examined in depth. For this reason, it is not clear how the cognitive structure is for concepts such as clean water and related sanitation, which concepts these concepts are associated with, and what the incorrect or incomplete understandings are. Although the concept of environment is the most common, there are also studies examining the cognitive structure for concepts such as recycling and renewable energy (Aktaş, 2021; Bakar, 2019; Çelik, 2019; Polat & Bahar, 2012; Özcan & Demirel, 2019; Özyurt & Yalman, 2020). In these studies, since the environment and environmental relations are questioned more generally, concepts such as water and water resources, sanitation, and hygiene have not been examined. However, it can be thought that the more correct the cognitive structure is about clean water, sanitation and its use, the easier it will be to prevent other negative situations related to the environment caused by unconsciousness in water use.

It will be possible to improve global water problems and prevent new problems with the contributions of all individuals, young and old. In particular, determining the cognitive status of the young generation on this issue can be considered important for the future. In a study conducted by Kariper (2014) on the awareness of university students about water pollution, it was revealed that although very simple and general questions were asked about the concepts of dirty water, water hardness, purification and disinfection, why or how water becomes dirty and how it becomes drinkable, students did not have enough knowledge about water pollution and could not comment on some issues, and even did not internalize the environment and water very much. Alaş et al. (2009) concluded in their study that teacher candidates did not pay attention to water saving. In biology departments of science faculties, education is provided on subjects such as living beings, nature and environment. Therefore, revealing the cognitive structures of students studying in this department about clean water and sanitation is essential in order to quickly eliminate misinformation and lack of knowledge before they start their professional lives. It is thought that revealing the necessary prior knowledge and alternative concepts of biology students about clean water and sanitation will help to organize the content of the courses given about environment and water resources during undergraduate education and to see the deficiencies in the field.

Based on all these, the problem of the research is “What are the cognitive structures of biology department students of science faculty about clean water and sanitation?” In order to serve this general purpose, the following sub-objectives are focused on:

1. What are the cognitive structures of biology department students about the concept of clean water?

2. What are the cognitive structures of biology department students about the concept of sanitation?

Methods

This research is a descriptive study designed in the survey method. Descriptive studies are used to understand the structure of objects, societies and the functioning of events (Cohen, Manion & Morrison, 2007). Since it is necessary to obtain a lot of information about a phenomenon in order to define it, a lot of data is needed (Metin, 2014:80). Another aspect of survey studies is that the sample makes generalizations about the universe that is thought to be represented in the light of the obtained data (Cohen et al., 2007). In this study, it was deemed appropriate to choose the survey method to determine the cognitive structures of the students in the biology department of the faculty of science about clean water and sanitation.

Data Collection Tool

In the research, WAT was used as a data collection tool to determine the cognitive structures of the students regarding the concepts of clean water and sanitation. The word association test reveals the connections between the concepts in the cognitive structure of the students and helps to determine whether the relationship between the concepts in the long-term memory is sufficient or meaningful (Bahar, Johnstone & Sutcliffe, 1999). In this technique, students are asked to write down the concepts that come to mind with a given key concept related to a topic within a certain period of time. The key concept chosen for the WAT is the concepts of clean water and sanitation. During the application of the test, university students were asked to write down the related concepts that come to mind with the key concept within 30 seconds. The thirty-second time period was determined as the most appropriate time period in the pre-tests conducted in previous academic studies (Ercan, Taşdere & Ercan, 2010; Özatlı & Bahar, 2010; Polat, 2013). The reason for writing the key concept ten times under each other is to prevent the risk of chain response. Because if the key concept does not return to the university student in each concept writing, he/she may write the words that come to mind with the concept he/she wrote as an answer instead of the key concept, which may prevent the test from achieving its purpose. Before the WAT was applied, students were given brief information about the word association test and examples from different fields were shown.

Sample

The sample of this study consists of a total 429 biology students studying at a university. The sample was determined by simple random sampling method. The voluntary participation of the students in the study was taken into consideration.

Analysis of Data

In order to determine the results of the KIT, the response words given to the key concepts of “Clean water” and “Sanitation” were examined. The response words given for the key concept were written one by one and a frequency table was created. During the analysis of the data, the response words given by the students to the key concept were used and analyses were carried out by the project owner and the consultant in order to ensure the consistency of the data. Common themes were obtained for each answer by performing content analysis. Inter-observer reliability calculation was made for the obtained themes. The numbers with consensus and disagreement in the common decisions were determined and calculated using the reliability=consensus/consensus+disagreement formula. At this point, 82% consensus was obtained for clean water and 81% consensus was obtained for sanitation. In this context, reliable coding was obtained by finding the scores above 80% for consensus (Kabapınar, 2003).

Findings and Discussion

The findings regarding the evocative words and sample sentences related to the concept of clean water in the word association test are presented in Table 1.

Table 1. Evocative words and example sentences for the concept of clean water

Theme	Code	Frequency	Total f	Example Sentences
Environment	Stream	14	47	Fruits and vegetables are thoroughly washed with clean water.Clean water is very important for living organisms in nature.Clean water is the most important element in the ecosystem.
	Living Being	7		
	Sea	6		
	Fish	5		
	Nature	4		
	Animal	4		
	Rain	3		
	Ecosystem	2		
	Habitat	2		
Soil	Mineral	10	24	Clean water contains minerals.Seas are blue in color.
	Plant	6		
	Soil	4		
	Blue	3		
	Agriculture	1		
Cleanliness	Hygiene	17	57	Water is essential for cleanliness.There must be clean water so the universe can be hygienic.The rain that fell was very clear.
	Cleanliness	12		
	Pure	10		
	Clear	9		
	Purified	7		
	Sterile	1		
	White	1		
Water Treatment	pH	4	18	Clean water can be obtained by boiling.Distillation purifies dirty water.The pH of clean water is 7.
	Chlorine-Free	4		
	Transparent	3		
	Distillation	3		
	Distilled	2		
	Boiling	1		
	Steam	1		
Life	Health	29	59	The most important thing for a healthy life is water.Clean water is necessary for a healthy life.Clean water gives people a sense of relief.
	Life	26		
	Relief	2		
	Compassion	1		
	Love	1		

When Table 1 is examined, it is seen that 5 themes were obtained for the concept of clean water. The theme of life consists of the word group that evokes the most for the word clean water. The theme of water purification is seen as the least used theme for the concept of clean water.

Among the most used words, words such as Health (29), Life (26) and Hygiene (17) stand out. Words that appear larger in the word cloud are words that are used more frequently (Figure 4).

When sample sentences about clean water were analyzed scientifically, scientific errors were revealed. Below are the findings consisting of misconceptions/misconceptions about clean water, the reason for the mistake and corrections to these concepts.

"Clean water can be obtained by boiling."

Incorrect: The boiling process can increase the hygiene of water, but this alone is not enough for water to be pure and clean. Purification and water taken directly from sources are healthier.

Correction: Clean water can be obtained by purification processes.

"There must be clean water so that the universe can be hygienic."

Incorrect: The word "universe" here has a very general and abstract meaning. The expression "the universe being hygienic" may not make much sense in a sentence describing the hygiene of water.

Correction: There must be clean water so that our living spaces can remain hygienic.

"Clean water is essential for a healthy life" and similar expressions (for example, "Clean water is very important for our health.")

Incorrect: Although all of these sentences are correct, they may be repetitive expressions. If they are used in a text, they should not be used in the same way every time.

Correction: It would be good to use variety in such sentences. For example, instead of "Clean water is essential for health.", different expressions such as "Clean water is the guarantee of a healthy life." can be used.

"Clean water is pure water that does not contain chemicals."

Incorrect: This sentence is correct, but we can clarify. The term "pure water" refers to the complete purity of water, especially in terms of chemistry and biology. Clean water, on the other hand, generally refers to water that is free of pollutants.

Correct: "Clean water is water that is free of pollutants and has not lost its natural properties."

"Clean water is transparent."

Incorrect: Clean water can be transparent, but it does not always have to be transparent. For example, even if mineral water is transparent, it contains minerals.

Correction: Clean water is usually transparent.

"Clean water should have a transparent color."

Incorrect: They are repetitive and the concept of transparency is not directly related to the cleanliness of water.

Correction: Clean water should be transparent and should not contain foreign matter.

"Water is essential for the life of living things."

Incorrect: This sentence is correct, but it could be more fluent.

Correction: Water is essential for the life of all living things.

The findings regarding the evocative words and sample sentences related to the concept of sanitation in the KİT test are presented in Table 2.

Table 2. Evocative words and example sentences for the concept of sanitation

Theme	Code	Frequency	Total f	Example Sentences
Nature	Living Being	6	31	• Sanitation is important for the environment. • Seas are not hygienic for sanitation. • Sanitation is a biology concept.
	Sea	4		
	Nature	4		
	Plant	3		
	Animal	3		
	Human	3		
	River	2		
	Soil	2		
	Ecology	2		
	Ocean	1		
	Biology	1		
Health	Health	16	56	• Sanitation must be done to stay healthy. • Dirt is cleaned with soap. • The process of separating undrinkable water from microorganisms to obtain clean water is called sanitation.
	Hygiene	17		
	Bacteria	7		
	Sterilization	4		
	Microorganism	5		
	Disinfection	3		
	Soap	1		
	Blood Pressure	1		
	Hospital	1		
	Second	1		
Water Treatment	Water	24	74	• Treatment is part of sanitation. • Cleaner water can be obtained through sanitation. • Boiling makes water cleaner.
	Treatment	15		
	Chlorine	9		
	Pure	8		
	Sewage	7		
	Distillation	5		
	Filtration	2		
	White	1		
	Boiling	2		
	Tap	1		
Waste	Pollution	14	37	• Sanitation can be the transformation of something. • Sanitation separates waste from dirt. • Sanitation is the transformation of wastewater.
	Waste	10		
	Transformation	6		
	Efficiency	3		
	Separation	2		
	Wastefulness	1		
	Chemical	1		
Planning	System	5	21	• Sanitation should be done regularly. • Sanitation is a process carried out with planned and specific mechanisms. • Sanitation is important for our health.
	Order	4		
	Process	4		

	Plan	2		
	Community	2		
	Facility	2		
	Mechanism	1		
	Important	1		
Environment	Environment	5	18	•Sanitation is economically costly. • Sanitation is necessary for efficient agriculture.
	Agriculture	3		
	Plant	3		
	Natural	3		
	Soil	2		
	Economy	1		
	Protection	1		

When Table 2 is examined, it is seen that 6 themes were obtained from the answers regarding the concept of sanitation. The theme of purification consists of the words that evoke the most for the concept of sanitation. The theme of environment consists of the words that evoke the least for the concept of sanitation. Among the most used words, words such as Water (24), Hygiene (17) and Health (16) stand out. Words that appear larger in the word cloud are words that are used more frequently.

When sample sentences about sanitation were analyzed scientifically, scientific errors were revealed. Below are the findings consisting of misconceptions/misconceptions about sanitation, the reason for the mistake, and corrections to these concepts.

"Purification is a part of sanitation."

Misconception: Purification and sanitation may be similar concepts, but they are not exactly the same. Sanitation generally refers to a broader cleaning and hygiene management. Purification, on the other hand, is the process of cleaning water or other substances from contaminants.

Correction: Water treatment is an important part of sanitation.

"Sanitation is done in facilities."

Misconception: Sanitation is not only done in facilities; it can also be applied in homes, cities, factories, and nature.

Correction: Sanitation is done in various environments, especially in facilities.

"Sanitation can be the transformation of something."

Misconception: The expression "transformation of something" is ambiguous here. Sanitation is generally the process of removing pollution, ensuring cleanliness, and creating hygienic conditions.

Correction: Sanitation is the process of eliminating environmental pollution.

"Drinking water is obtained by sanitation."

Incorrect: Drinking water is not obtained directly by sanitation. Sanitation is the process of cleaning water, but the water must be purified initially.

Correction: Drinking water is provided by sanitation and purification processes.

"Sanitation is a biological concept."

Incorrect: Sanitation may be related to biology, but it is not directly a biological concept. It is related to environmental hygiene, cleanliness and health.

Correction: Sanitation is a process related to environmental health and hygiene.

"Sanitation is the main part of cleanliness."

Incorrect: Sanitation not only provides cleanliness, but also regulates hygiene and health conditions.

Correction: Sanitation is a process that regulates hygiene and health conditions as well as cleanliness.

"The process that separates non-consumable water from microorganisms and enables us to obtain clean water that can be drunk is called sanitation."

Incorrect: This sentence is complicated and long. In addition, the processes of water purification and sanitation could be stated more clearly.

Correction: Sanitation is a process that makes water drinkable by removing microorganisms.

Conclusion and Recommendations

1. The associations for the concept of clean water are grouped under 5 themes.

2. The most associated theme for the concept of clean water is Life, while the least used theme is Water Purification.

3. The most commonly used words for the concept of clean water are: health, life, and hygiene.

4. Scientific inaccuracies include the views that clean water can only be obtained by boiling or that transparency is the only indicator of cleanliness.

5. The associations for the concept of sanitation are grouped under 6 themes.

6. The most commonly used theme for sanitation is purification, while the least commonly used theme is environment.

7. The most commonly used words for the concept of sanitation are: water, hygiene, and health.

8. Scientific inaccuracies include the views that sanitation can only be done in facilities or that it is a directly biological concept.

9. Many scientific concepts related to clean water and sanitation have been used incorrectly.

10. Expressions such as "Let the universe be hygienic" in the sample sentences have a very general or abstract meaning.

11. The majority of students have understood how important water is for living things and its relationship with health.

12. There is a general consensus that water must be clean.

13. It has been understood that purifying water is necessary to obtain clean water.

14. There is confusion about what exactly concepts such as sanitation and purification mean.

15. There are incorrect generalizations such as water must always be transparent.

16. Ambiguous and incorrect uses such as "Sanitation can be the transformation of something" are striking.

17. It is not fully understood that sanitation is not only about water but also a broader concept of environmental hygiene.

18. There is a lack of information about different water purification methods and their working principles.

19. There is a lack of information about not only the physical properties of water but also its chemical properties.

This study aimed to reveal students' associations with the concepts of water and sanitation and their cognitive structures on this subject. The findings show that students understand the importance of water but have deficiencies in the scientific dimensions of these concepts. For example, simple misconceptions such as "Boiling provides clean water" indicate that the hygiene and purification processes of water are not sufficiently understood.

Students generally associate water and sanitation with basic concepts such as life, health and hygiene. However, it is observed that they lack knowledge on more specific issues such as purification and the environment. This situation can be interpreted as these issues are not sufficiently covered in the curriculum or that students cannot relate these issues to their daily lives.

Another important point that emerged in the study is that students have scientific misconceptions. Misconceptions such as water can only be cleaned by boiling or that sanitation can only be done in facilities stem from students' lack of scientific knowledge. This situation emphasizes the importance of providing students with more accurate and comprehensive information.

Confusing similar concepts such as sanitation and purification also shows that students do not fully understand the nuances between these concepts. This situation suggests that the concepts should be defined more clearly and supported with examples.

In the literature, misconceptions are often emphasized in the context of environmental education. According to Ausubel's Meaningful Learning Theory, students' incorrect or incomplete prior knowledge makes it difficult for them to understand new information. Therefore, constructivist approaches should be adopted on environmental health, water properties, and sanitation processes.

Studies examining students' perceptions of water and sanitation concepts provide significant knowledge on this subject. Researchers such as Gilbert and Boulter (2000) state that students tend to simplify complex scientific concepts and this leads to misconceptions. Especially concepts that need to be supported visually, such as the water cycle, can be challenging for students.

Studies in the field of environmental education also examine students' awareness of the importance of water resources and pollution problems. For example, in a study conducted by Özerdinç and Hamalosmanoğlu (2021), it was determined that students did not have sufficient knowledge about the protection of water resources and their sensitivity on this issue was low. This situation shows that more effective environmental education programs should be developed for students.

There are also different pedagogical approaches developed to eliminate misconceptions about water and sanitation in the literature. For example, it is stated that methods such as experimental learning, problem solving and project-based learning deepen students' conceptual understanding and contribute to permanent learning.

The literature emphasizes that the materials used in water and sanitation education also play an important role in students' learning processes. Visual materials, simulations and realistic models can help students concretize abstract concepts. However, in order to use these materials effectively, teachers must have pedagogical knowledge and skills.

Finally, it is emphasized that water and sanitation education is linked to sustainable development goals and plays an important role in raising students as individuals who are sensitive to the environmental problems they will encounter in their future lives. Therefore, water and sanitation education should not only be based on scientific knowledge, but should also be designed in a way that shapes students' value judgments and behaviors.

Misconceptions about clean water and sanitation indicate a lack of awareness that this concept is not limited to obtaining clean water, but also includes hygiene and environmental health processes. These concepts are of vital importance not only for individual but also for social health. Therefore, the following suggestions can be given in connection with the emerging cognitive structure and the resulting misconceptions/misconceptions:

- Scientific truths and practical examples should be added to the course content about clean water and sanitation.
- The differences between boiling, purification and hygiene processes should be explained clearly for students.
- Concept tests should be regularly applied to identify students' misconceptions and feedback should be provided.
- Education programs should be rearranged on the sustainability of water resources and the importance of sanitation.

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EXAMINATION OF SCIENCE FACULTY STUDENTS' OPINIONS ON THEIR PROFESSIONAL PREFERENCES AND REASONS

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ABSTRACT

Although teacher training policies in Turkey have been around for over a century, the teacher training model has not been sustainable. Although it has been removed from time to time, teachers continue to be trained with the pedagogical formation program outside of education faculties. It is obvious that students of science faculty, one of the faculties participating in pedagogical formation training, do not start their education-teaching life only with the aim of becoming teachers. When it is considered that the main purpose of science faculties is to train scientists, the questions of why their students turn to pedagogical formation and why they choose the teaching profession by moving away from the general purpose of the faculty come to mind. Therefore, the aim of this research is to examine the reasons for the profession preferences of science faculty students with their justifications. The survey method was used in this research. The sample of the research consists of 429 students studying in the 1st and 4th grades of the Faculty of Science at Sivas Cumhuriyet University. The data of the study was obtained with the help of a survey consisting of open-ended questions. The obtained data was analyzed using content analysis. As a result of the study, it was seen that science faculty students' own desires were the most effective in their career choices and that they mostly preferred the mathematics department. In addition, it was seen that science faculty students' reasons for turning to the teaching profession were being useful, comfort and job opportunities. The relevant views are also similar for 1st and 4th year students. In order for students to make conscious decisions in their career choices, it is important to increase career guidance services, promote interdisciplinary fields and develop policies to increase the attractiveness of the teaching profession.

Keywords: Faculty of science, career choices, teaching profession

Introduction

The aim of universities is to train professionals who are equipped and qualified in their fields (Başer 1994). In order to receive a university education in Turkey, it is necessary to have a certain score and ranking. In this way, it is ideal for students to be placed in the professions that they dream of and that are close to their areas of interest. However, research indicates that career choices are largely based on economic factors, and therefore people's career choices differ from their real interests (Behymer & Cockriel, 2005; Kniveton, 2004). The situation is not much different for the teaching profession, because research draws attention to the role played by external factors in choosing the teaching profession (Bastick, 2000; Boz & Boz, 2008; Papanastasiou & Papanastasiou, 1998). Studies investigating the career preferences of prospective teachers indicate that career preferences are shaped based on factors in three main categories (Bastick, 2000; Boz & Boz, 2008; Brown, 1992; Chuene, Lubben & Newson, 1999; Kyriacou & Coulthard, 2000; Saban, 2003). One of the most important points that distinguishes the teaching profession from other professions is that it has some affective characteristics (Alım et al., 2018). In Article 43 of the National Education Basic Law No. 1739, it is defined as "a special specialized profession that undertakes the education, training and related administrative duties of the state" and it is stated that "teachers are obliged to perform these duties in accordance with the objectives and basic principles of Turkish National Education" (MEB, 2018). Teacher training has been seen as a very important field throughout history. Although teacher training policies in Turkey have been around for over a century, the teacher training model has not been sustainable. In Turkey, in addition to the task of training teachers being given to faculties of education in 1982, the pedagogical formation program has been structured many times. The Council of Higher Education (YÖK) closed the pedagogical formation programs in the 1997-1998 academic year, claiming that they were far from being implemented and inadequate in terms of content and duration, and decided that the education period would be carried out in two ways: 3.5+1.5 years for students of faculties of education and 4+1.5 years for graduates of faculties of science and literature. Later, with the decision it made in 2010, a new application was initiated and students who graduated from many different departments, including senior students of faculties of science and literature, were given the right to apply for teaching in specified fields. YÖK abolished the formation program once again in 2012, but later decided to continue it again. With the latest change, pedagogical formation education can now be given as an elective course in all faculties.

Historically, where, how and by whom teachers will be trained has always been a matter of debate. In this respect, it is seen that the relevant literature examines the perceptions, self-efficacy, attitudes and metaphors of teacher candidates and pedagogical formation students towards the teaching profession (Alım et al., 2018; Çocuk, Yokuş & Tanrıseven, 2015; Gün, 2017; Kiraz, & Dursun, 2015). In pedagogical formation education, the target audience is generally science faculties, social sciences faculties, literature faculties, and faculties such as engineering and architecture can also benefit. It is obvious that science faculty students do not start their education and training lives only with the aim of becoming teachers. When it is considered that the main purpose of science faculties is to train scientists, the question of why students turn to pedagogical formation and why they prefer the teaching profession by moving away from the general purpose of the faculty comes to mind. However, it is seen that the relevant literature bases its examinations on education faculty graduates or pedagogical formation program students in terms of the teaching profession. No research has been found on why these students turn to the teaching profession before or during the process. Considering that with the latest regulation, teaching profession courses can be taken as elective courses for students in formal education programs starting from the 3rd semester, it is important to see how

the examination changes during the academic years. In addition, it is thought that examining various dimensions of the pedagogical formation process through scientific methods will provide a more pedagogical approach to these discussions. It is planned that the current study will form the basis for the changes to be made both in teacher education and formation training in terms of revealing and justifying the reasons for the "teaching profession" choice of students in science faculties. The implementation process of the project will constitute an example for determining the professional tendencies of science faculty students. It is thought that the current project will form the basis for investigating the professional preferences in other faculties and determining the relationships in terms of the teaching profession. The problem of the research is "What are the professional preferences and justifications of science faculty students?"

The aim of this project is to examine the reasons for the career choices of science faculty students with their justifications. In order to serve this general purpose, the following sub-objectives are focused on.

1. What are the career choices of science faculty students according to their departments at the beginning of their education?

2. What are the reasons for the career choices of science faculty students according to their departments at the beginning of their education?

3. What are the career choices of science faculty students according to their departments at the end of their education?

4. What are the reasons for the career choices of science faculty students according to their departments at the end of their education?

5. Why do science faculty students turn to the teaching profession?

Methods

The scanning method was used in this study. This method, also known as field scanning or survey, is a type of research conducted to determine the current situation (Çepni, 2012). The easiest method to use to reach a large sample is surveys. Scanning studies basically have a descriptive structure. This research method is used to make sense of the structure of objects, institutions or societies and the functioning of events (Cohen, Manion & Morrison, 2007). Since it is necessary to obtain a lot of information about any phenomenon in order to define it, scanning studies are usually carried out based on a large amount of data (Metin, 2014:79-80). Since it is desired to determine the situation of science faculty students in their career choices in this project, it was deemed appropriate to use the scanning method in terms of the need for a large sample and to find answers to many questions that come to mind about the subject. The cross-sectional scanning method, which is one of the scanning methods, was used in the study. Cross-sectional scanning, in which data collection is carried out at a single time, is similar to taking a photograph of the universe at any moment (Metin, 2014: 81). The characteristics of a section in time were described for the examined career choice phenomenon.

Sample of Study

Simple random sampling method was used in the sample selection of this research. The sample of the research consists of 429 students studying in the 1st and 4th grades of the Faculty of Science at Sivas Cumhuriyet University.

Data Collection Tools

The data of the study were obtained using surveys consisting of open-ended questions. A survey is a data collection tool used to determine the opinions of the sample in a short time and

systematically in order to get answers to the questions determined about a subject (Metin, 2014: 164). It is possible to collect a wide variety of data with the survey method. We can reveal people's opinions on many subjects such as feelings, behaviors, attitudes, and knowledge through surveys (Çepni, 2012: 212). The students were asked the following questions within the scope of the survey: "Which professions did you prefer in your university preferences?" "Explain in detail the reasons for your preference of these professions." "What is your reason for turning to the teaching profession?" They were asked to write their opinions by leaving a blank space under the survey questions. The survey questions were applied face to face.

Analysis of Data

The data collected with the surveys in the study were analyzed with content analysis. The main purpose of content analysis is to reach concepts that can explain the obtained data (Yıldırım & Şimşek, 2005). First, the surveys were divided into departments and classes. The transcripts, which are the data, were read in detail before the coding process. Within the scope of content analysis, the data were coded and categorized, themes were found, and the data were organized according to codes and themes. In the last stage, the themes obtained from the data were interpreted and the meaning integrity was ensured. The relevant themes and codes were also made by another expert in the field of education. A consensus was reached on the themes and codes obtained. Data losses occurred in the data due to incomplete answers given to some questions.

Findings and Discussion

Below are the findings regarding the data obtained regarding the career preferences and reasons of the science faculty students.

Table 1. The most preferred departments by freshman students in the Faculty of Science

Preferences	B	P	C	M	MBG	S	f	%
Mathematics	4	5	5	57			71	24.23%
Molecular Biology & Genetics (MBG)	6				51		57	19.45%
Biology	39				8		47	16.04%
Physics	3	28	6		4		41	13.99%
Nursing/Midwifery	4	4	4	16	12		38	12.97%
Software/Cybersecurity		8				17	25	8.53%
Biochemistry	5					4	9	3.07%
Engineering	5						5	1.71%
Total	66	45	14	73	75	21	293	100%

B: Biology, P: Physical, C: Chemistry, M: Mathematics, MBG: Molecular Biology and Genetics, S: Statistic

When Table 1 is examined, it is seen that the department most preferred by the students of the faculty of science is mathematics (%24.23) and the department least preferred by them is engineering (%1.71). It is seen that the students of the biology department prefer their own department the most and prefer the physics department the least. It is seen that the students of the physics department prefer their own department the most and prefer the nursing and midwifery department the least. The students of the chemistry department prefer the physics

department the most and prefer the nursing and midwifery department the least. The students of the mathematics department prefer their own department the most and prefer the nursing and midwifery department the least, the students of molecular biology and genetics prefer their own department the most and prefer the physics department the least, the students of the statistics department prefer the software and cyber security department the most and prefer the biochemistry department the least.

Table 2. Career choice reasons of freshman students in the Faculty of Science

Reason	P	C	B	M	MBG	S	Total (f)	%
Own interest	9	5	16	21	21	6	78	39.80%
Job opportunities	4		13	6	9	7	39	19.90%
Recommendation	3	6	8	4	11		32	16.33%
Exam score / ranking			13	6	9		28	14.29%
Pressure / Obligation		5	5		4	5	19	9.69%
Total	16	16	55	37	54	17	196	100%

When Table 2 is examined, it is seen that the students of the science faculty department mostly chose their professions because of their own will (39.80%) and least because of pressure and necessity (9.69%). The students of the physics department mostly chose this department because of their own will. The students of the chemistry department mostly chose this department because of recommendation. The students of the biology department mostly chose this department because of their own will. The students of the mathematics department mostly chose this department because of their own will. The students of the statistics department preferred this department because of job opportunities.

Table 3. The most preferred departments by senior students in the Faculty of Science

Department	P	C	B	M	MBG	S	Total (f)	%
Mathematics			3	40		2	45	38.46%
Physics	14						14	11.97%
Physiotherapy (PT)				6	6		12	10.26%
Statistics						11	11	9.40%
Biology	2		8				10	8.55%
Faculty of Education	4		5				9	7.69%
Chemistry		6	3				9	7.69%
Nursing			4				4	3.42%
Engineering						3	3	2.56%
Total	20	6	23	46	6	16	117	100%

When Table 3 is examined, it is seen that the department most preferred by 4th grade students is the mathematics department (%38.46) and the department they least preferred is the

engineering department (%2.56). Physics department students preferred their own department the most and the biology department the least. Chemistry department students preferred only their own department. Biology department students preferred their own department the most and the chemistry and mathematics department the least. Mathematics department students preferred their own department the most and the physical therapy and rehabilitation department the least. Molecular biology and genetics students preferred only the physical therapy and rehabilitation department, statistics department students preferred their own department the most and the mathematics department the least.

Table 4. Career choice reasons of senior students in the Faculty of Science

Reason	F	K	B	M	MBG	İ	Total (f)	%
Own interest		6	7	20		4	37	44.58%
Job opportunities		3		5	7	3	18	21.69%
Recommendation		4	3	5		5	17	20.48%
Pressure / Obligation	8				3		11	13.25%
Total	8	13	10	30	10	12	83	100%

When Table 4 is examined, it is seen that 4th grade students mostly preferred their professions by their own will (44.58%) and least by necessity (13.25). All of the physics department students preferred due to pressure and necessity. Chemistry department students mostly preferred because of their likes and least because of job opportunities. Biology department students mostly preferred because of their likes and least because of environmental factors. Mathematics department students mostly preferred their departments by their own will and least because of environmental and job opportunities. Molecular biology and genetics students mostly preferred because of job opportunities and least because of necessity. Statistics department students mostly preferred because of environmental factors and least because of job opportunities.

Table 5. Reasons for Science Faculty students to choose the teaching profession

Reason	F	K	B	M	MBG	İ	f	%
To be useful	5		5	17	12	3	37	27.41
Comfort	3	2	5	11	4		26	19.26
Job opportunity	5	6	1	7	5		24	17.78
Childhood dream		2	3	5	3		13	9.63
Interest/Love	2	3	3	2	1		11	8.15
Respected profession	2		3	2	4		11	8.15
Suitable for women		2	3		2	1	8	5.93
Family wish		2			3		5	3.70
Total	17	17	23	44	31	7	135	100

When Table 5 is examined, it is seen that the reasons why science faculty students turn to the teaching profession are to be useful (27.41%) and the least because their families want it (3.70%). Physics department students turned to the teaching profession mostly because of job opportunities and being useful. Chemistry department students turned to the teaching profession mostly because of job opportunities. Biology department students preferred the teaching profession mostly because they saw it as a useful and comfortable profession. Mathematics department students preferred the teaching profession mostly because of being useful. Molecular biology and genetics students turned to the teaching profession mostly because of being useful. Statistics department students turned to the teaching profession mostly because of being useful and their families wanting it.

Conclusion and Recommendations

The following results were obtained within the scope of the study:

1. It was observed that the first-year students of the faculty of science preferred the mathematics department the most and the engineering department the least.

2. It was revealed that the first-year students of the faculty of science preferred the profession mostly by their own will and least out of necessity.

3. It was observed that the senior students of the faculty of science preferred the mathematics department the most and the engineering department the least.

4. It was observed that the senior students of the faculty of science preferred the profession mostly by their own will and least out of necessity.

5. It was observed that the reasons for the students of the faculty of science to turn to the teaching profession were mostly due to the idea of being useful and least due to family requests.

The findings obtained show that the factors determining the profession preferences of the students of the faculty of science are shaped by both individual and environmental dynamics. The fact that the mathematics department is the most preferred department among both the first-year and final-year students reveals that the advantages offered by the mathematics branch in terms of job opportunities are realized by the students. Individuals who graduate from the mathematics department have access to a wide job market thanks to their analytical thinking and problem-solving skills. This can be considered as one of the basic factors that guide the preferences of science faculty students. The increasing importance of STEM (science, technology, engineering and mathematics) fields in the global labor market supports the popularity of basic sciences such as mathematics.

The fact that physical therapy and rehabilitation and education faculties are rarely included in the preferences of senior students suggests that the popularity of these fields is decreasing. In the literature, the reasons for the decline in the professional status of education and health fields include the increasing number of graduates and the decrease in the financial satisfaction of these professions (Çifçi, Bülbül, Bayar Muluk, Çamur Duyan, & Yılmaz, 2011). On the other hand, the preference for disciplines such as software/cyber security and nursing shows that the attractiveness of these professions has increased due to the impact of technology and digitalization.

Most of the students stated that they chose the departments of their own volition. Although there are many issues such as field of interest, score and ranking in career choices, it can be said that science faculty students are mostly studying in science branches with their own will. In

addition, it is among the results obtained that job opportunities and recommendations are also important in career choices.

Science faculty students have also stated a small number of education faculties among their most preferred departments in the 4th grades. This may be due to the fact that the scores are not enough for education faculties. However, it is seen that departments such as software and cyber security are also preferred despite being higher than science faculties in terms of score and ranking. For this reason, it can be said that science faculty students prefer fields such as software and cyber security and nursing more than teaching profession even if their scores are sufficient.

The fact that students' own interests and desires are at the forefront in their career choices emphasizes the importance of individual motivations and career goals. However, it has been observed that factors such as obligations and environmental pressures also affect preferences. In the literature, it is stated that individual interest, score-ranking pressure, family expectations and economic conditions are among the factors affecting career choices (Vurucu, 2010). In this context, the fact that students' scores are not sufficient for education faculties or that they exclude some preferences due to ranking pressure shows the restrictive effect of the higher education system in Turkey on students. This situation can be evaluated as a reason for the limited preferences especially for the teaching profession.

The fact that the idea of being useful to people is at the forefront among the reasons for turning to the teaching profession shows that the profession has a social benefit-oriented structure. It is stated in the literature that tendencies towards the teaching profession are shaped by motivations such as childhood dreams, perception of social benefit and job security (Ekinci, 2017). However, it is stated that low salaries and negative perceptions about the social status of the profession limit this preference. In addition, the fact that formation courses in science faculties have become elective is another factor affecting the number of students considering the teaching profession. This situation causes the tendency towards the teaching profession to be limited to a more conscious and limited group of students.

As a result, it can be said that factors such as individual interest, job opportunities, family pressure and score-ranking are effective in the career preferences of science faculty students. The popularity of the mathematics department is a result of the fundamental sciences' position in the labor market.

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WILD PLANTS CONSUMED AS FOOD IN MUŞ PROVINCE AND THEIR USES

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ABSTRACT

In this study, wild plants that are widely used in Muş Province and consumed by collecting from nature and their usage methods were investigated. The majority of the people in Muş utilise the plants collected from nature with the arrival of spring, either fresh or cooked. In Muş, mostly *Arum* sp., *Asparagus officinalis* L., *Crataegus* sp., *Eremurus spectabilis* BIEB., *Ferula* sp., *Gundelia tournefortii, Lepidium* sp., *Malva sylvestris* L., *Mentha longifolia, Nasturtium officinale, Ornithogalum wiedemannii, Tragopogon* sp., *Urtica dioica* L., *Plantago* sp., *Polygonum* sp., *Portulaca oleracea* L., *Pyrus elaeagnifolia, Rheum ribes* L., *Rumex* sp. were used as food. These plants are organic because they grow in nature. They are rich in vitamins, minerals and essential oils and have a special place in human nutrition as most of them are also medicinal plants. Population densities and distribution areas of these plants collected from nature as food are gradually decreasing. Plant collection should be carried out by conscious people in a controlled manner. In addition, it is useful to carry out cultivation and breeding studies in endangered species and species that can be grown economically.

Keywords: Muş province, Natural plants, wild edible plants, plant collection.

MUŞ İLİNDE GIDA OLARAK TÜKETİLEN YABANİ BİTKİLER VE KULLANIM ŞEKİLLERİ

ÖZET

Bu çalışmada Muş İli'nde yaygın olarak kullanılan ve doğadan toplanarak tüketilen yabani bitkiler ve bunların kullanılma şekilleri araştırılmıştır. Muş'ta halkın büyük çoğunluğu ilkbaharın gelmesi ile birlikte doğadan toplanan bitkileri taze olarak ya da pişirerek, değerlendirmektedir. Ayrıca bu tüketim alışkanlığı bitkileri değişik şekillerde muhafaza ederek yıl boyunca devam etmektedir. Muş'ta daha çok *Arum* sp., *Asparagus officinalis* L., *Crataegus* sp., *Eremurus spectabilis* BIEB., *Ferula* sp., *Gundelia tournefortii*, *Lepidium* sp., *Malva sylvestris* L., *Mentha longifolia*, *Nasturtium officinale*, *Ornithogalum wiedemannii*, *Tragopogon* sp., *Urtica dioica* L., *Plantago* sp., *Polygonum* sp., *Portulaca oleracea* L., *Pyrus elaeagnifolia*, *Rheum ribes* L., *Rumex* sp. türlerinin gıda olarak kullanıldığı tespit edilmiştir. Bu bitkiler doğada yetiştiği için organiktir. Vitamin, mineral ve esensiyal yağlar bakımından zengindir ve çoğu aynı zamanda şifalı bitki olduğu için insan sağlığı açısından ayrı bir yeri vardır. Doğadan gıda olarak toplanan bu bitkilerin popülasyon yoğunlukları ve yayılış alanları giderek azalmaktadır. Bitki toplamalarının kontrollü olarak bilinçli kişiler tarafından yapılması gerekmektedir. Ayrıca tehlike altında olanlarda ve ekonomik olarak yetiştirilebilecek türlerde kültüre alma ve ıslah çalışmaları yapılmasında fayda vardır.

Anahtar Kelimeler: Muş ili, Doğal bitkiler, yabani yenilebilen bitkiler, bitki toplama.

GİRİŞ

Ülkemizde doğada kendiliğinden yetişen otsu bitkilerin sebze olarak tüketimi oldukça yaygındır. Tüm dünyada olduğu gibi ülkemizde de doğal florada bulunan bitkilerin halk arasında tedavi amaçlı, gıda, çay, baharat vb., olarak kullanımı uzun yıllardan beri süregelen geleneksel kültürel zenginliğimizin bir parçası olmuştur. Ancak bu olgu şehirleşmeyle paralel olarak kaybolmaya başlamıştır (Faydaoğlu ve Sürücüoğlu, 2011).

Yabani bitkilerin kültür bitkilerine göre mineral madde ve vitaminler bakımından daha zengin olduğu bilinmektedir (Doğan ve ark., 2004; Alarcón, R., ve ark., 2006; Doğan, 2013). Ayrıca önemli miktarda kalsiyum, fosfor ve demir gibi mineralleri de içermektedirler (Alarcón ve ark., 2006; Aktan ve Bilgir, 1978). Ayrıca yapılan bazı çalışmalar, sağlıklı diyetin önemli bir parçası olarak kabul edilen yenilebilir otların yaşlılıkla ilintili hastalıkların geciktirilmesinde önemli bir potansiyele sahip olduğunu belirtmektedir. (Knight, 2000). Gıda olarak kullanılan bu bitkiler, çiğ veya pişmiş olarak yenildiği gibi kurutularak, salamura halinde veya turşu şeklinde de tüketilmektedir (Faydaoğlu ve Sürücüoğlu, 2011).

Dünya genelinde gıda olarak kullanılan yabani bitki türlerinin 10.000'nin üzerinde olduğu rapor edilmiştir (Baytop, 1999; Yücel ve ark., 2010; Yücel ve ark., 2011). Anadolu'da gıda, çay, atıştırmalık, koku ve tat vericilerle beraber 1200 civarında doğal bitkiden gıda olarak yararlanıldığı belirtilmiştir (Ertuğ, 2014).

Yenilebilen yabani bitkilerle ilgili sahip olduğumuz kültürel mirasın korunması ve gelecek nesillere aktarılabilmesi için, tür ve çeşitlerimizin kayıt altına alınması oldukça önemli bir konudur. Bu konunun hayata geçirilmesi için ise bahsedilen bitkilerin halk tarafından çeşitli kullanım şekillerinin tespit edileceği etnobotanik çalışmaların ülke genelinde başlatılarak sürdürülmesi gerekmektedir (Kargıoğlu ve ark., 2008; Satıl ve ark., 2008).

Yenilebilir otlardan çorbalar, sebze yemekleri, sarma ve salatalar yapıldığı gibi, özel aromaya sahip olanlar taze ve kurutularak tat verici olarak mutfaklarda kullanılmakta ve çay olarak içilmektedir. Yemek olarak kullanılan otlar bir anlamda sebzelerin kendiliğinden yetişenleridir (Baysal, 2003).

İyigün ve Özer (2001), Muş ili ve çevresinde gıda olarak tüketilen yabancı otları araştırmak amacı ile yürüttükleri çalışmada, yörede en fazla gıda olarak tüketilen yabancı ot türlerinin; *Eremurus spectabilis Bieb., Salvia sclarea* L.,*Gundelia tournefortii* L., *Amaranthus retroflexus* L., *Urtica dioica* L., *Urtica urens* L., *Silene vulgaris (Moench) Garcke., Capsella bursa-pastoris (*L.*) Medik., Rumex crispus* L., *Mentha aguatica* L., *Portulaca oleracea* L. olduğunu bildirmişlerdir.

Bu çalışmada Muş İlinde yaygın olarak doğadan toplanarak gıda olarak tüketilen yabani bitkiler ve bunların kullanım şekilleri belirlenmeye, aktarılmaya çalışılmıştır. Bu bitkilerin değerlendirme şekillerinin kaybolmadan gelecek kuşaklara aktarılması, kayıt altına alınması yanında, bu bitmez tükenmez sanılan hazinenin, sürdürülebilirliği ve korunmasına dikkat çekmek amaçlanmıştır.

Materyal ve Metot

Bu çalışma; 2024 yılında Doğu Anadolu Bölgesi'nde yer alan Muş ili sınırları içerisinde yapılmıştır. Muş, Doğu Anadolu Bölgesi'nin Yukarı Murat-Van Bölümü'nde yer almaktadır. Yaklaşık 8116 km² yüz ölçümü bulunmaktadır. Kuzeyde Erzurum, güney ve güneybatıda Bitlis, Diyarbakır ve Batman, batıda Bingöl ile doğuda Ağrı ve Bitlis illeriyle komşudur. Bölge 3000

metre yüksekliği geçmeyen engebeli dağlık araziler ve 1200-1500 metre yükseltideki ovalık arazilerden oluşmaktadır. Muş, gündüz ile gece sıcaklık farkının yüksek olduğu, donlu, soğuk ve uzun kışların geçtiği karasal iklim tipine sahiptir. Yıllık sıcaklıklar kışın ortalama -10 °C yazın ise 25 °C'nin üzerindedir. Yağış miktarı ise yıllık ortalama 765 mm'dir (Sönmez, 2010).

Saha çalışmasında Muş'ta doğadan toplanarak gıda olarak tüketilen bitkilerin kullanım şekilleri hakkında, kadınlar başta olmak üzere 16 kaynak kişiye şifaen sorular sorulmuş ve elde edilen bilgiler aktarılmıştır. Çalışmada literatür bilgilerinden de istifade edilmiştir. Kaynak kişilere ait bilgiler Çizelge 1'de verilmiştir.

Çizelge 1. Kaynak kişiler ve bilgileri

Kaynak kişi	Adı-Soyadı	Cinsiyeti	Yaşı	Yerleşim Yeri
KK1	A. Y.	**E**	**52**	Durugöze köyü/Merkez/Muş
KK2	B. Ç.	**K**	**65**	Varto/Muş
KK3	E. E.	**K**	**33**	Merkez/Muş
KK4	F. Y.	**K**	**50**	Ilıca köyü/Merkez/Muş
KK5	F. A.	**K**	**53**	Korkut/Muş
KK6	F. K.	**K**	**46**	Soğucak köyü/Merkez/Muş
KK7	H. Y.	**K**	**75**	Durugöze köyü/Merkez/Muş
KK8	H. Ç.	**K**	**35**	Merkez/Muş
KK9	L. İ.	**K**	**54**	Bulanık/Muş
KK10	M. A.	**K**	**46**	Merkez/Muş
KK11	N. A.	**K**	**55**	Bulanık/Muş
KK12	R. E.	**K**	**48**	Alan içi köyü/Merkez/Muş
KK13	S. K.	**K**	**45**	Arpayazı köyü/Merkez/Muş
KK14	S. T.	**K**	**35**	Merkez/Muş
KK15	S. S.	**K**	**37**	Merkez/Muş
KK16	S. Ü.	**K**	**55**	Merkez/Muş

Araştırma Bulguları ve Tartışma

Muş İlinde gıda amaçlı yaygın olarak toplanan bitkiler Çizelge 2'de verilmiştir.

Çizelge 2. Muş İlinde Gıda Amaçlı Yaygın Olarak Toplanan Bitkiler

Bitkinin latince adı	**Türkçe adı**	**Yöresel adı**	**Familyası**	**Kullanılan kısmı**
Arum sp.	Yılanyastığı	Karî-Karik-Kardî	Araceae	Herba
Asparagus officinalis L.	Kuşkonmaz	Melajo	Liliaceae	Sap
Chaerophyllum bulbosum L.	Orman maydanozu-Frenk maydanozu	Mendik-Mendo	*Apiaceae*	Herba
Crataegus sp.	Alıç	Givîj	Rosaceae	Meyve
Eremurus spectabilis BIEB.	Çiriş, Dağ pırasası	Gulik, Gülbahar	Liliaceae	Herba
Ferula orientalis L.	Çakşır-Kasnı	Cağ	Apiaceae	Herba ve Kök
Ferula szowitsiana DC.	Çakşır	Heliz	Apiaceae	Sap
Gundelia tournefortii var. *tournefortii*	Kenger	Kereng, dardak	Asteraceae	Kök ve Sap
Lepidium sp.	Dağ teresi	Kersim	Brassicaceae	Herba
Malva sylvestris L.	Ebegümeci	Tolık	Malvaceae	Yaprak
Mentha longifolia subsp. *typhoides* var. *typhoides*	Yarpuz	Punk	Lamiaceae	Yaprak
Nasturtium officinale R. BR.	Su teresi	Kıce	Brassicaceae	Herba
Ornithogalum wiedemannii BOISS var. *wiedemannii*	Tükürük otu	Spidak, Serbışk	Liliaceae	Herba
Tragopogon sp.	Yemlik	Sipînk	Asteraceae	Herba
Urtica dioica L.	Isırgan	Gezgezok-Gezgezg	Urticaceae	Herba
Plantago lanceolata L.	Dar yapraklı sinir otu		Plantaginaceae	Herba
Plantago sp.	Sinirli ot	Pelheves	Plantaginaceae	Yaprak
Polygonum sp.	Madımak	Nane, civika	Polygonaceae	Herba
Portulaca oleracea L.	Semizotu	Parpar	Portulacaceae	Herba
Pyrus elaeagnifolia PALLAS	Ahlat, yaban armudu	Karçin	Rosaceae	Meyve
Rheum ribes L.	Işkın	Ribes, uçkun, eşkın, yayla muzu	Polygonaceae	Kök ve Sap
Rumex sp.	Kuzukulağı, Labada	Tirşo	Polygonaceae	Herba, tohum

Muş İlinde doğadan yaygın olarak toplanarak tüketilen bitkilerin kullanılış şekilleri Çizelge 3'de verilmiştir.

Çizelge 3. Muş ilinde doğadan yaygın olarak toplanan bitkilerin kullanım şekilleri

Latince ve Türkçe adı	**Kullanım Şekilleri**
Arum sp. Yılanyastığı	Taze tüketim şekli bulunmamaktadır. Toplanıp örülür ve asarak kurutulur. Kış aylarında yemek yapmak için kullanılır. Yemek yapımında toplanan ve örülen otlar sıcak suyla iyice haşlanır. Acılığından dolayı haşlama ve süzme işlemi 3 defa tekrar edilir. Suyu süzüldükten sonra haşlanmış olan otlar sos eşliğinde yağda güzelce pişirilir.(sos: soğan ve tereyağının ayrı bir kapta kavrulmasıyla elde edilir.) (KK13). Mevsiminde toplanıp kurutulur. Kışın kaynar suda haşlanır, suyu süzülür, pancarı* yada çorbası yapılır (KK10). Önce kurutulur daha sonra salça ve soğan ile yağda kavrulur (KK5; KK9). Önce orta boy içli köfte hazırlanır. Sonra 100 gr. kuru gari (yılanyastığı) kaynatılıp süzülür. Yarım çay bardağı zeytinyağı soğanla kavrulur, salça eklenir, biraz daha kavrulur. Üzerine bir su bardağı haşlanmış yeşil mercimek, bir su bardağı haşlanmış yarma, bir su bardağı haşlanmış nohut, bir çay bardağı tanesi kaynatılmış sumak suyu konur, suyu ayarlanır kaynatılır. Kıvam alınca içli köfteler atılır, piştikten sonra afiyetle yenir (KK2). Kurutulmuş olan yılanyastığı suda haşlanır, yumuşatılır, ayrı tavada soğan kavrulur, yılanyastığı eklenir kavrulur, üzerine yumurta kırılarak servis yapılır (KK15).
Asparagus officinalis L Kuşkonmaz.	Kesilen bitkiler soğuk suda yıkanır. Kuşbaşı olarak doğranır. Az suda haşlanır ve hafif ateşte yağda kızartılıp üstüne yumurta kırılarak servis edilir (KK6). Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra çıkarılarak yumurta ile kızartılarak tüketilir (KK5A; KK9). Haşlanarak ekşili salatalarda kullanılır ya da domates sosu ile soteleyerek zeytinyağlı olarak pişirilip tüketilir (KK11).
Chaerophyllum bulbosum L. Orman maydanozu	Yaprakları atılıp gövdesi haşlanıp kışlık olarak bidonlarda tuzlu su ile saklanır. Kış ayında tüketilir. Tüketimi çakşır otu ile aynı şekilde olmaktadır. Suda haşlanır, sonra yağda yumurta ile kavrulur (KK1; ;KK15; KK16). Turşusu yapılır. Kışın yumurtaya bulanıp kızartılır Turşusu yapılır. Kışın yumurtaya bulanıp kızartılır (KK14). Salamura yapılır bir iki hafta olgunlaşması beklenir sonra çökelek veya peynirde kullanılır. Haşlayıp sonra kavrulur, un ve yumurta karışımı üstüne dökülüp biraz daha pişmesi sağlanır daha sonra yenilir. Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra direk yemeklerin yanında tüketilir (KK5A; KK9). Toplanan bitkiler temizlenir, sirke ile turşusu yapılır, sarardıktan sonra çökelek veya peynire katılır (KK11).
Crataegus sp. Alıç	Meyve olarak tüketildiği gibi çay olarak demlenerek te tüketilir (KK10; KK11). Marmelatı yapılır (KK10). Meyve olarak direk yenilir. Ezilerek çekirdeği çıkarılır sonra reçel kıvamında tüketilir (KK5; KK9).
Eremurus spectabilis Çiriş	Yemek yapmak için az suda haşlanır, suyu süzülüp sıkılır. 1. Yağda kızartılıp üstüne yumurta kırılabilir. 2. Çorba yapılacaksa soğuk suda yıkanır, kuşbaşı şeklinde doğranır, içine bulgur veya pirinç atılarak bol suyla pişirilir ve sos eşliğinde servis edilir. (sos:tereyağında salça pul biber, kuru soğan ile kavrulur ve çorbanın üstüne gezdirilir (KK4). Önce haşlanır, sonra yumurta ile yağda kavrulur. Ayrıca tavuk eti ile çiriş beraber haşlanıp dövülerek ezilir ve çalma denilen bir yemek yapılır (KK16). Çiriş yumurta ile kavrulur ya da yumurta un ile de kavrulabilir (KK3). Bulgur veya buğdayla çorbası yapılır. Pide ve Pancarı yapılır. Ispanak gibi kavrulur (KK10). Baş ve Kök kısmı kesilir yıkandıktan sonra haşlanır derin dondurucuda muhafaza edilir kullanılmak istendiğinde yumurta ile kavrularak yenilir veya böreklerin içinde ıspanak gibi kullanılır (KK5; KK9). Çiriş otunun kök kısmında bir zar olur bu zar çıkarılır, bitki yaprak yaprak ayrılır. Sonra bir kapta su içerisine konur biraz bekletilir akabinde birkaç kere güzelce yıkanır. Süzgeçe alınır, suyu alındıktan sonra doğranır. Tencerede önce zeytinyağı konur, soğanlar yemeklik doğranır, 3 dakika kısık ateşte kavrulur, üzerine salça eklenir 1-2 dakikada böyle kavrulduktan sonra çirişler eklenir. Kısık ateşte çirişler yumuşayınca, bulguru, suyu, tuz ve biberi eklenir, kapağı kapatılır, kısık ateşte çirişler yumuşayıncıya kadar pişirilir ve sonra tüketilir (KK11; KK15).
Ferula orientalis L. Çakşır-Cağ	Haşlanan çakşırlar suyu elde iyice süzüldükten sonra küçük küçük doğranmakta ve bir süre yağda kavrulmaktadır. Daha sonra daha önceden bir kabın içine kırılmış, çırpılmış ve içine tuz ilave edilmiş yumurtalar kavrulan çakşırın üzerine dökülmekte ve yumurtalarla birlikte bir süre piştikten sonra yenmektedir. (KK7). Yeşil yaprakları ve gövdesi yumurtaya bulayarak kızartma şeklinde, haşlama veya turşu formunda tüketilebiliyor. Kökü kaynatılıp içilir (Sever ve Yenikalaycı, 2024). Toplandıktan sonra turşu gibi tuzlu suda bidonlara kurulur, fermente edilir. Turşu hali haşlanır, yumuşayınca yumurta, un, süt karışımına bulanarak yağda kızartılır (KK3; KK16). Turşusu, pancarı ve yumurtalı kızartması yapılır (KK10). Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra çıkarılarak yumurta ile kızartılarak ya da direk yemeklerin yanında tüketilir (KK5; KK9). Çay olarak tüketilir. Bunun için bir tatlı kaşığı toz veya kökü kaynar suya konur 15 dakika bekletilir, sonra süzülerek içilir. Toplanan otlar ayıklanır ve iyice yıkanır. Küçük küçük doğranır, kendi suyunda haşlanır ve sonra sıkılır. Tencerede önce soğan kavrulur, üzerine otlar eklenir. Tuz, karabiber eklenir. Son olarak üzerinde açılan çukurlara yumurta kırılır. Turşusu da yapılır. Bunun için ayıklanıp temizlenen çakşırlar tencerede bol suda yumuşayıncıya kadar haşlanır, bol tuzla harmanlanıp kavanoza konur ağzı hava almayacak şekilde iyice kapatılır, buzdolabında bir hafta bekletilir. Çakşırlar ekşiyip salamura halini alınca tüketilir (KK11).
Ferula szowitsiana	Taze olarak tüketilirse zehirlenmeye sebep olur, saç örgüsü gibi yapılır ve kurutulur, sonra tüketilir.

DC. Çakşır-Heliz	Yemekleri yapılır (Sever ve Yenikalaycı, 2024). Haşlandıktan sonra çökelek ile yağda kavrulur (KK16). Turşusu yapılır. Peynir yapımında (otlu peynir gibi) ve pancarı yapılır (KK10). Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra direk yemeklerin yanında tüketilir. Kurutulup keledoş isimli yöresel yemekte kullanılır (KK5; KK9). Turşusu çakşır gibi yapılır. Tencerede kaynatılır, sonra yağda kızartılır, üzerine yumurta kırılarak tüketilir (KK11).
Gundelia tournefortii Kenger	Yemek olarak tavada kızartma yapılacaksa, soğuk suyla temizce yıkanır. 5 dk kaynar suya haşlanıp soğuk suya bırakılır sonra bidonlara doldurulup üstüne tuzlu su eklenip en az 20 gün bekletilir. 20 gün sonra bidonlardan yeteri miktarda alınıp. Daha öncesinde yapılmış olan yumurta un ve süt (çiğ olarak bulunan) karışıma yatırılıp sonrasında kızarmış yağlı tavada pişirilir. (KK7; KK15). Dardak (Kenger) (Gundelia tournefortii): Yaşlanmış kengere yöresel olarak Dardak denir. Gövdesi toplanır, dikenlerinden ayırt edilir ve gövdesi soyularak yenir. (KK1). Un, yumurta ve yoğurt ile çorbası yapılır (KK16). Turşu, pancar yemeği yapılır. Bir de ayran aşına katılır (KK10). Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra çıkarılarak yumurta ile kızartılarak tüketilir. Diğer bir kullanım şekli ise ayran aşı çorbasına (yöresel adı: Gırar) haşlanıp ilave edilir. Haşlanıp bulgur pilavı içerisine katılarak tüketilir. Tuzlu su ile salamura (Turşu) yapılır 15-20 gün bekletildikten sonra direk yemeklerin yanında tüketilir (KK5; KK9). Kengerler koyu kabuklarından ayrılır, temizlenir. 15 dakika suda bekletilir, yıkanır. Tencerede bol suda haşlanır, sonra süzgeçe alınır. Tavaya yağ konur, eriyince yumurta kırılır, süzgeçteki kengerler avuç içerisinde sıkılarak tavaya konur, kavrulur, tuz, biber eklenir ve yenir. Çiğ olarakta tüketilir (KK11).
Lepidium sp. Dağ teresi	Temiz yaprakları toplanır ve güzelce yıkanıp sıcak su ile haşlanır. Çekilmiş buğday (dövme buğdaydan) ile sarması yapılır. Sarımsaklı yoğurt ile servis edilir. (KK7). Haşlanıp sarma yapılarak tüketilir (KK5; KK9).
Malva sylvestris L. Ebegümeci	Pancar yemeği* yapılır (KK10). Kurutulup çay gibi demlenir ve suyu içilir. Çorbaların içine de katılarak tüketilir. Haşlanıp süzüldükten sonra sarımsaklı yoğurt ile tüketilir veya yumurta ile pişirilerek yenilir (KK5; KK9). Ebegümeci yaprakları ve sapları ince ince doğranır. Bir tencerede soğanlar 5 dk. kavrulduktan sonra ebegümeci eklenir ve yumuşayıncaya kadar kavrulur, ara sıra karıştırılır. Salça eklenir karıştırılır, bulgur eklenir karıştırıldıktan sonra sıcak su ilave edilir, tuzu eklenir. Kısık ateşte ara ara karıştırarak suyu çekinceye kadar pişirilir ve tüketilir. Ebegümeci kurutulup çayı da yapılır (KK11; KK15).
Mentha longifolia Yarpuz	Yöresel olarak yapılan ayran aşı çorbasına çeşni vermesi için katılır. Kuru yapraklarından yapılan bitki çayı mide rahatsızlığında kullanılır. (Sever ve Yenikalaycı, 2024). Ayran aşı denilen yoğurtlu çorbalara taze olarak konur (KK16). Kurutulup baharat olarak kullanılır. Çiğ olarak da tüketilir (KK10). Kurutulup çay gibi demlenir ve suyu içilir. Ayrıca çorbaların içine de yaş veya kurutulmuş olarak özellikle ayran aşı çorbasında kullanılır (KK5; KK9). Ekşili punk (yarpuz) yemeği yapılır. Bunun için aşurelik buğday ve nohut haşlanır. Buğday tencereye konur haşlanır, nohut üzerine konur birlikte karışım sağlanır, üzerine yarpuz eklenir karıştırılır ve kaynatılır. Diğer tarafta bir tavada sıvı yağ konur, salça eklenir kavrulur, pul biber eklenir, karıştırılır, kaynayan tencereye dökülür, önceden suya koyduğumuz ekşili sumak suyu konur ve yemek hazır olur (KK11) .
Nasturtium officinale Su teresi	Çiğ olarak sebze gibi tüketilir (KK5A; KK9).
Ornithogalum wiedemannii Tükürük otu	Yemek yapımında taze yapraklar güzelce soğuk suyla yıkanır, yağda hafif ateşte pişirilir isteğe bağlı olarak pul biber ve üzerine yumurta kırılarak servis edilir. Örgü yapılarak kurutulan bitkilerde ise ilk başlangıçta güzelce yıkanır sonra sıcak suya doğranır ve haşlanır, sıcak sudan alınıp suyunun süzülmesi beklenir. Sonrasında yağ, kuru soğan ve pul biber eşliğinde hafif ateşte iyice pişirilir isteğe bağlı olarak üzerine yumurta kırılabilir. (KK12; KK15) Soğanla beraber küçük şekilde doğranır, açılan hamur içine konur, sonra mantı gibi haşlanır ve tüketilir. Mevsiminde toplanıp kurutulur. Suda haşlanıp kavrulur. Buğdayla da çorbası yapılır (KK10). Yaş hali erken ilkbaharda toplanır saç örgüsü gibi bağlanıp gölgede kurutulur. Yemek yapılacağı zaman ihtiyaç kadar kesilir ve keledoş yemeğinin içerisinde kullanılır. Direk haşlanarak üzerine sarımsaklı yoğurt katılarak yemeğide yapılır. Katı çorba (Yöresel ismi: Gebol) olarakta tüketilir (KK5; KK9).
Tragopogon sp. Yemlik	Çiğ olarak tüketilir (KK15). Bazen diğer otlarla haşlanıp pancar* gibi tüketilir (KK14.). Yıkandıktan sonra direk veya tuz ile tüketilir. Yaprakları kaynatılarak haşlanır ve derin dondurucuda saklanır. Sonra yumurta ile veya direk olarak kavrulup tüketilir (KK5; KK9; KK11).
Urtica dioica L. Isırgan	Isırgan otu çorbalara katılmakta, haşlanmakta, yumurta ve soğan gibi malzemelerle kavrulmakta ve çiğ olarak tuza bandırılıp tüketilmektedir. Isırgan otu çorbası: Isırgan otları ayıklanıp bol suda yıkanır ve doğranır. Bir tencerede soğanlar zeytinyağıyla birlikte kavrulur. İçerisine ısırgan otları ve un eklenerek birkaç dakika daha kavrulmaya devam edilir. Sonra bir miktar süt yavaş yavaş ilave edilerek durmadan karıştırılır. Su, tuz ve karabiber eklenerek pişirilir. Çorbanın daha lezzetli olmasını sağlamak için kemik suyu ile pişirilmesi önerilmektedir (KK13). Soğan, pirinç ve salça ile çorbası yapılır (KK16). Pancarı yapılır. Böreklerde ve salatada kullanılır (KK10; KK14.). Domates, soğan ve yumurta ile beraber menemen gibi kahvaltıda tüketilir. Kurutularak veya taze olarak çorbası yapılır veya Kurutulmuş yaprakları kışın çay olarak tüketilir. Haşlanıp süzüldükten sonra yoğurt ile tüketilir veya yumurta ile pişirilerek yenilir (KK5; KK9). Toplanan ısırganalar yıkanır, küçük küçük doğranır, haşlanır, sonra tavada yağda salça kavrulur, üzerine haşlanan ısırganlar, bulgur, tuz ve su

	eklenir pişirilir (KK15).
Plantago lanceolata L.	Çiğ olarak sebze gibi tüketilir (KK5; KK9).
Plantago sp. Sinirli ot	Çiğ olarak mide rahatsızlığı için tüketilir. Pancarı yapılır (KK10;KK14.). Yaş halinde toplanarak salamura yapılır. Sarma yaparak tüketilir (KK5; KK9).
Polygonum sp. Madımak	Diğer otlarla haşlanıp pancar* şeklinde kavrulup yenir (KK10; KK14; KK15). Muş'ta yemek olarak tüketilir (Sever ve Yenikalaycı, 2024).
Portulaca oleracea L. Semizotu	Muş'da sıkça tüketilen hem çiğ olarak hem de pişirilerek yenilen bir sebze türüdür. Anadolu'nun birçok yerinde semizotu olarak adlandırılmaktadır. Diğer isimleri ise temizlik otu, soğukluk ve can otudur. Mayıs ve Haziran aylarında yetişmekte, Temmuz ve Ağustos aylarında toplanmaktadır. Mutfakta oldukça geniş bir kullanıma sahiptir. Çiğ olarak salatalarda ve pişirilerek yemeklik olarak değerlendirilmektedir. Parpar yemeği: Soğanlar yemeklik doğranır ve pembeleştikten sonra kuşbaşı etle salça ilave edilir. Bir süre daha kavrulan yemeğe parparlar ve bulgur eklenir. Bir miktar su eklendikten sonra sebzelerin vitaminini öldürmemek için çok kısık ateşte pişirilir (KK12). Haşlanır, yoğurt, pul biberi ve yağ eklenerek servis yapılır, Çiğ hali ile salatalarda tüketilir (KK16). Çorbası, salatası ve yemeği yapılır. Çorbası pirinçli veya bulgurlu olabilir. Yoğurtlu, sarımsaklı salatası yapılır. Ayrıca kıymalı bulgurlu yemeği de yapılır (KK3). Taze olarak yendiği gibi birde kurutulup kompostoya katılır (KK10; KK14.). Çiğ olarak toplanıp salata yapılarak tüketilir. Haşlanıp süzüldükten sonra yoğurt ile tüketilir veya yumurta ile kavrularak yenilir (KK5; KK9).
Pyrus elaeagnifolia Ahlat	Meyve olarak yenilir (KK5; KK9). Toplanan küçük armutlar ince ince doğranır, güneşte kurutulur, kışın hoşafı yapılır (KK15).
Rheum ribes L. Işkın	Erzurum'da ışkın kabuğu soyularak tuza batırılıp çiğ olarak yenmektedir. Ülkemizde bazı yörelerde ışkınlı yumurta veya fırında ışkın gibi isimlerle pişirilerek tüketildiği de görülmektedir. (KK4). Doğu Anadolu Bölgesinde ilkbahar aylarında değişik şekillerde gıda maddesi olarak tüketilmektedir. Işkınlı yumurta, kavurma, kapuska yapıldığı gibi ekşili yemeği, turşusu ve ışgınlı dondurma gibi ürünler yapılmaktadır. Pişirilerek veya sebze olarak da kullanımı vardır (Yenikalaycı, 2023). Kabukları soyulup meyve olarak yenilir. Kökü haşlanıp, tüketilir özellikle şeker hastaları tercih eder (KK5; KK9). Soylarak çiğ tüketilir, ekşimsi bir tadı vardır (KK11).
Rumex sp. Kuzukulağı	Kuzukulağı çorbası: Bir tencereye yağ konur, kuzukulağı ve küçük küçük doğranmış patatesler eklenerek kavrulur. Et suyu ilave edilir, kaynamaya bırakılır. Kaynayan çorbaya krema ve limon sıkılır. Karabiber serpilerek servis edilir (KK6). Yaprakları taze olduğunda çiğ olarak tüketilebilmektedir. Ekşi bir tada sahiptir ve tuzlanarak yendiğinde daha lezzetli olduğu düşünülmektedir. Böreklerin içinde, çorbalarda ve bazı yemeklerde kullanılır (KK6). Haşlanır sonra yumurta ile yağda kavrulur. Pirinçli sarması da yapılır (KK16). Salatalarda tüketilir (KK10; KK14.). Hafif haşlanır sonra sarma yapılıp yenilir. Kurutulur soğan ile pişirildikten sonra yenilir. Kurutulup ekşi tadından dolayı nane gibi çorbaların üstüne katılarak yenilir (KK5; KK9).

*:Pancar ya da pancar yemeği: Otlar yıkanır küçük küçük doğranır, sonra suyu süzülür, tavada soğanı kavrulur, haşlanan, suyu sıkılan otlar üstüne eklenir yağda kavrulur, isteyen yumurta kırar veya istemeyen serviste üstüne sarımsaklı yoğurt ekler. Yoğurdun üstüne kızgın tereyağ dökülür. Sonra afiyetle yenir. Otlarla kavrularak yapılan bütün yemeğe Muş'ta pancar ya da pancar yemeği denir. Yöresel ağızda böyle söylenir (KK10.).

Sonuç ve Öneriler

Muş İli geniş ovaları ve verimli toprakları ile büyük bir tarımsal potansiyele sahiptir. Diğer illerden farklı olarak Muş'ta hala tarımla uğraşan nüfus oranı % 70 civarındadır. İlde doğadan toplanarak tüketilen bitkiler çok fazladır. Muş halkı doğadaki bitkilerden maksimum düzeyde istifade etmektedir. Doğadan toplanan bitkiler batı illerine de büyük miktarda gönderilmekte, bir ekonomik değere ve kazanca dönüşmektedirler. İlde Bu bitkiler sadece ilkbahar aylarında değil, su içerisinde bidonlarda bekletilerek, salamura yapılarak ya da kurutularak yıl boyunca kullanılmaktadır. Halk genel olarak et tüketimi yanında doğal bitkilerden yeterince faydalandığı için obezite oranı da düşüktür, caddelerde aşırı kilolu çok fazla insan göremezsiniz. Bu otların tüketme şekli diğer illere benzemekle birlikte, Muş'ta kendine özgü bir şekilde bunları etlerle, yumurta veya et suyu ile lezzetlendirme, besin değerini böylece artırma biçimi farklılık gösterebilir. Bir bakıma yabani otlar ile ana yemekler yapılmaktadır.

Muş'ta doğadan büyük oranlarda bitki toplanması doğa tahribatına ve bitki türlerinin azalmasına neden olmaktadır. Bitki toplamada dengeli, bilinçli bir politika izlenmesi gerekiyor. Bitkilerin en azından % 15-20'sinin doğada bırakılarak çiçeklenmesine, tohum bağlamasına ve

neslinin devamına fırsat verilmesi sürdürülebilirlik açısından önemlidir. Işkın gibi bazı bitkilerde bitki kökleri şeker hastalığına karşı kullanıldığı için kökleri ile sökülmekte, doğada bitki tamamen yok edilmektedir. Doğadan bitki toplayarak geçimini sağlayan kişilerin gelecek yıllarda gelirlerinin devam etmesi için bu konuda bilinçli ve insaflı olması gerekiyor. Bu doğal hazinenin insan beslenmesindeki önemini dikkate alarak sürdürülebilirlik açısından bitki toplayıcıların belli bir eğitimden geçmesi ve toplamalarının Tarım ve Orman Bakanlığı kontrollünde, denetimli yapılması daha uygun olabilir. Toplanan bitkilerin vejetasyondaki durumlarının araştırılarak, tehlike altında olanlar veya yoğunluğu azalan türlerde kültüre alma ve ıslah çalışmaları yapılmasına ihtiyaç vardır. Bu bitkilerin aynı zamanda yetiştiriciliğinin yapılması durumunda ekonomik olacağı savunulabilir.

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Şekil 1. Muş'ta bahar aylarında toplanan yabani bitkilerin caddelerde satılışı.
Fotoğraf: Ahmet Yenikalaycı

IMPROVEMENT OF SURFACE PROPERTIES OF Az31 MAGNESIUM ALLOY COATED BY MICRO-ARC OXIDATION

MİKRO-ARK OKSİDASYON İLE KAPLANMIŞ AZ31 MAGNEZYUM ALAŞIMININ YÜZEY ÖZELLİKLERİNİN GELİŞTİRİLMESİ

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ÖZET

Magnezyum alaşımlarının düşük yoğunluk ve yüksek mukavemet/ağırlık oranı gibi avantajlarına rağmen, sınırlı korozyon direnci endüstriyel uygulamalarını kısıtlamaktadır. Bu çalışmada, AZ31 magnezyum alaşımının korozyon ve mekanik özelliklerini iyileştirmek amacıyla Mikro-Ark Oksidasyon (MAO) yöntemi kullanılarak ZnO katkılı ve katkısız kaplamalar büyütülmüştür. Büyütülen kaplamaların yapısal karakterizasyonu Taramalı Elektron Mikroskobu (SEM) ve X-Işını Difraksiyonu (XRD) analizleriyle gerçekleştirilmiştir. Korozyon özellikleri ve tribolojik davranışları, potansiyodinamik polarizasyon ve aşınma testleri ile değerlendirilmiştir. Sonuçlar, ZnO katkılı kaplamaların daha düşük gözeneklilik, yüksek mekanik stabilite ve gelişmiş korozyon direnci sağladığını göstermiştir. En iyi performans, 10 dakika işlem süresi, 600 V pozitif voltaj ve ZnO katkılı elektrolit çözeltisi kullanılarak elde edilmiştir. Bu bulgular, MAO işlem parametrelerinin optimize edilmesiyle

yüzey özellikleri iyileştirilen AZ31 magnezyum alaşımlarının endüstriyel uygulamaları için kullanım ömürlerinin daha da artacağını ortaya koymaktadır.

Anahtar kelimeler: Yüzey modifikasyonu, Mikro-Ark Oksidasyon, Magnezyum Alaşımı, Kaplama, Korozyon direnci, Tribolojik özellikler

Giriş

Magnezyum (Mg), sahip olduğu olağanüstü özellik kombinasyonu sayesinde hem bilimsel araştırmalar hem de endüstriyel uygulamalar için son derece önemli bir malzeme olarak öne çıkmaktadır. Havacılık, otomotiv, elektronik ve hatta savunma sanayii gibi sektörlerde verimliliği artırmak amacıyla daha hafif sistemlere olan talebin artmasıyla, magnezyum alaşımları ilgi çekici hale gelmeye başlamıştır. Düşük yoğunluğu (1,74 g/cm³), yüksek sönüm kapasitesi, üstün geri dönüştürülebilirliği ve yüksek mukavemeti ile modern mühendislik çözümleri için vazgeçilmez bir tercih haline gelmiştir. Son yıllarda yaşanan gelişmeler ile, özellikle ağırlık azaltımının kritik olduğu uygulamalarda, enerji tüketimini azaltma ve performansı artırma konuları kritik bir önem arz etmektedir. Örneğin, magnezyum alaşımlarının çelik ve alüminyum gibi geleneksel malzemelere kıyasla ağırlık-mukavemet oranları açısından üstün performans gösterdiği, bu sayede ulaşım ve altyapıda enerji verimliliği ile sürdürülebilirliğe önemli katkılar sağladığı rapor edilmiştir (Luo 2017; Masood Chaudry vd., 2022). Ayrıca, devam eden araştırmalar, hafif araç bileşenleri ve yüksek performanslı havacılık yapıları gibi ileri üretim uygulamalarında magnezyumun kullanımını araştırmaya devam ederek, küresel verimlilik ve sürdürülebilirlik zorluklarının çözümünde büyük bir potansiyele sahip olduğunu ortaya koymaktadır (Ren vd. 2018; Zeng vd. 2019; Kumar vd. 2021). Bu özellikler, magnezyumu gelecekteki teknolojik gelişmeler için hafif yapısal malzemeler inovasyonunun temel taşı olarak konumlandırmaktadır.

Magnezyum alaşımlarından biri olan AZ31 magnezyum alaşımı, yüksek mukavemeti, mükemmel işlenebilirliği ve hafiflik özellikleri sayesinde endüstriyel uygulamalarda en yaygın kullanılan malzemelerden biri olarak kendini kanıtlamıştır. Bu özellikler, AZ31'i özellikle havacılık ve otomotiv sektörlerinde, ağırlık azaltımının performanstan ödün vermeden sağlanmasının kritik olduğu yapısal uygulamalara uygun hale getirmektedir (Jana vd. 2021). Bununla birlikte, tüm avantajlarına rağmen, AZ31 sert ve klorür bakımından zengin ortamlarda korozyona karşı yüksek hassasiyet açısından ciddi bir sorunla karşı karşıyadır. Bu dezavantaj, korozyon direncini artırmaya yönelik gelişmiş yüzey işlemlerini araştıran kapsamlı çalışmaların yapılmasını teşvik etmiştir (Song ve Xu 2010). Bu sorunu çözmek amacıyla, AZ31'in korozyon direncini ve mekanik özelliklerini geliştirmeyi hedefleyen çeşitli yüzey modifikasyon teknikleri geliştirilmiştir. Bu teknikler arasında, Mikro-Ark Oksidasyon (MAO), oldukça etkili bir yöntem olarak öne çıkmaktadır. MAO işlemi sırasında yüzeyde oluşturulan kalın, yoğun ve sağlam/kararlı bir oksit tabakası, alaşımın korozyon ve aşınma direncini önemli ölçüde artırmaktadır. Araştırmalar, MAO ile işlenmiş AZ31'in, tuzlu su ortamları ve ağır sanayi kullanımları gibi zorlu koşullarda daha dayanıklı ve yüksek performanslı olduğunu ortaya koymuştur (Lu vd. 2024). Ayrıca, karbon ve benzeri katkı maddelerini içeren ileri MAO varyasyonları, yalnızca korozyon direncini artırmakla kalmayıp, kaplamanın sertliğini ve aşınma direncini de artırarak malzemenin uygulama alanlarını daha da genişletmiştir (Hsu vd. 2019). Bu yüzey işlemlerinin entegrasyonu, AZ31'in yüksek performans gerektiren endüstriyel uygulamalardaki etkinliğini önemli ölçüde artırmıştır. Doğal sınırlamalarını yenilikçi teknolojilerle aşarak, AZ31, mühendislik ve üretim alanlarında çok yönlü ve güvenilir bir malzeme olarak konumunu güçlendirmeye devam etmektedir (Qiao vd. 2015). Son yıllarda, AZ31 magnezyum alaşımlarının yüzey özelliklerini iyileştirerek korozyon direncini artırmaya yönelik çalışmalar giderek artmıştır. Hafifliği ve mekanik avantajları nedeniyle yaygın olarak kullanılan AZ31, agresif çevre koşullarındaki korozyon hassasiyetini gidermek için genellikle gelişmiş yüzey işlemleri gerektirmektedir.

Bu çalışmada, AZ31 magnezyum alaşımının yüzeylerine koruyucu oksit kaplamalar oluşturmak amacıyla Mikro-Ark Oksidasyon (MAO) tekniği, iki farklı çözelti ile

uygulanmıştır. İlk çözelti, potasyum hidroksit (KOH), sodyum metasilikat (Na_2SiO_3), sodyum hidrojen fosfat (Na_2HPO_4) ve sodyum alüminat ($NaAlO_2$) içerirken, ikinci çözelti ise bu çözeltiye ek olarak çinko oksit (ZnO) içermektedir. Bu çözeltilerin kaplamaların yapısal, tribolojik ve kimyasal davranışlarına olan etkileri araştırılmıştır.

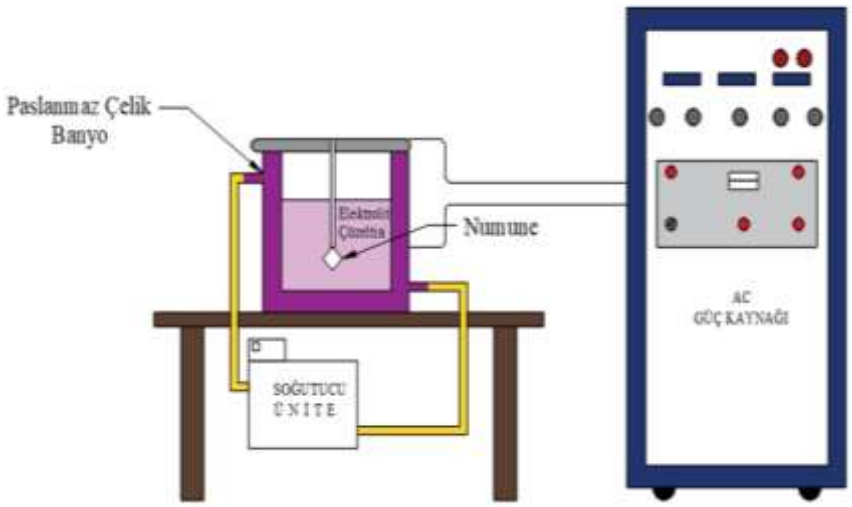
Materyal ve Metot

Mikro-Ark Oksidasyon (MAO) işlemi için kimyasal bileşimi Tablo 1' de verilen AZ31 magnezyum alaşımı taban malzemesi (25× 25×5 mm) kullanılmıştır. Numuneler, yüzey pürüzlülüğünü azaltmak ve homojen bir yüzey elde etmek amacıyla 120, 240, 480, 800, 1000 ve 1200 mesh silisyum karbür (SiC) aşındırıcılar içeren su zımparalarıyla sırasıyla parlatılmıştır. Parlatma işleminin ardından numuneler, alkol ile ultrasonik olarak temizlenmiş ve soğuk hava ile kurutularak MAO işlemine hazır hale getirilmiştir.

Tablo 1. AZ31 Mg alaşımının kimyasal bileşimi

Element	Al	Zn	Fe	Cu	Mn	Ni	Si	Mg
% Ağırlık Oranı	2.60	0.86	0.0015	0.0012	0.2859	0.001	0.0092	Balance

AZ31 Magnezyum alaşımı üzerine kaplama işlemleri Şekil 1'de şematik olarak verilen Faraday Elektronik Ltd. şirketi tarafından üretilen kaplama sistemiyle mikro ark oksidasyon (MAO) işlemi gerçekleştirilmiştir. İşlem boyunca numune anot, paslanmaz çelik hazne katot olarak kullanılmıştır. MAO kaplama işlemi, deneysel gruplar arasında karşılaştırma yapabilmek amacıyla iki farklı elektrolit çözeltisinde gerçekleştirilmiştir. Deney grupları, uygulanan elektrolit bileşimi ve işlem süresine göre kodlanmıştır. Bu kapsamda, birinci çözeltide işlem gören numuneler PR1-5dk, PR1-10dk ve PR1-20dk olarak, ikinci çözeltide (ZnO katkılı) işlem gören numuneler ise PR2-5dk, PR2-10dk ve PR2-20dk olarak tanımlanmıştır. Bu kodlamalar makale boyunca deneysel karşılaştırmaların takibini kolaylaştırmak amacıyla kullanılmıştır. İlk çözeltide 4 g/L sodyum metasilikat (Na_2SiO_3), 2 g/L potasyum hidroksit (KOH), 2 g/L sodyum hidrojen fosfat (Na_2HPO_4) ve 3 g/L sodyum alüminat ($NaAlO_2$) bulunmaktadır. İkinci çözeltide ise birinci çözeltiye ek olarak 2 g/L çinko oksit (ZnO) kullanılmıştır. Pozitif voltaj 600 V, negatif voltaj -120 V olarak ayarlanırken frekans 300 Hz ve görev döngüsü +%20/-%10 olacak şekilde belirlenmiştir. Oksidasyon işlemi, iki farklı solüsyon kullanılarak deneysel koşullara bağlı olarak 5, 10 ve 20 dakika sürelerle gerçekleştirilmiştir. Kaplama parametleri Tablo 2'de gösterilmiştir. İşlem tamamlanınca kaplama yapılmış numuneler saf su ile yıkanmış ve kurutulmuştur.



Şekil 1. Mikro ark oksidasyon (MAO) kaplama sisteminin şematik görüntüsü

MAO kaplamasının kristal yapı analizi, Panalytical Empyrean markalı X-Ray difraktometresi (XRD) ile gerçekleştirilmiştir. Kaplanmamış ve kaplanmış numunelerin XRD analizleri, oda sıcaklığında, 10^0 ila 100^0 arasında, $0{,}05^0$ adımda ve 1^0/dk tarama hızında Cu Kα radyasyonlu (λ=1.54060 Å) cihaz kullanılarak gerçekleştirilmiştir. Kaplamaların kalınlıklarını, morfolojisini incelemek ve element analizi yapmak için ZEISS EVO LS10 markalı taramalı elektron mikroskobu (SEM) kullanılmıştır.

MAO kaplanmış AZ31 alaşımı numunelerin korozyon davranışını belirlemek için potansiyodinamik polarizasyon testi kullanılmıştır. Potansiyodinamik polarizasyon ölçümleri için Versa-Stat marka cihaz kullanılmıştır. Numuneler %3,5 derişimli Sodyum Klorür (NaCl) çözeltisinde, atmosfer şartlarında üç elektrot tekniğiyle yapılmıştır. Numuneler açık devre potansiyeline ulaşıncaya inkadar bekletilmiş, ardından -1000/1000 mV potansiyel aralığında 1 m/V sn'lik tarama hızıyla potansiyodinamik olarak polarize edilmiştir.

Kaplamaların aşınma direncini belirlemek amacıyla tribolojik testler gerçekleştirilmiştir. Sürtünme katsayısı ölçümleri, sabit yük ve hız altında karşıt yüzeyle belirli bir kayma mesafesinde sürtünme davranışını izleyen bir CSM Tribometre ile gerçekleştirilmiştir. Testler, kuru ortam koşullarında 100 m'lik bir kayma mesafesi boyunca yapılmış ve her numune için sürtünme katsayısı (μ) çevrime bağlı olarak kaydedilmiştir. Aşınma izlerinin morfolojisi optik mikroskop ile incelenmiş ve her numunenin yüzey hasarı değerlendirilmiştir.

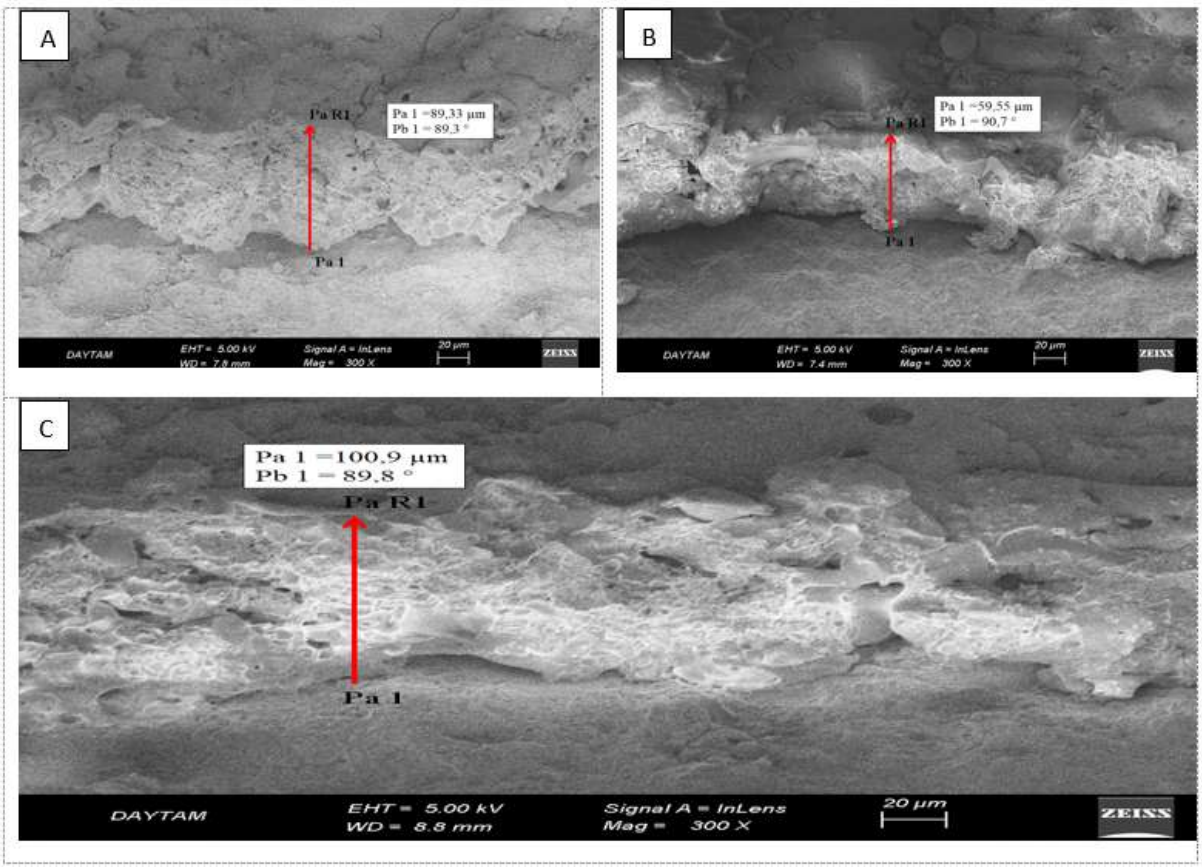
Tablo 2. Kaplama Parametreleri

Kaplama Parametreleri	Değerler
Taban Malzeme	AZ31
Pozitif Voltaj	600 V
Negatif Voltaj	-120 V
Frekans	300 Hz
Görev Çevrimi	+%20 / -%10
Kaplama Süresi	5 dk, 10 dk, 20 dk
I. Elektrolit Bileşimi	4 g/L Sodyum Metasilikat
	2 g/L Sodyum Hidrojen Fosfat
	3 g/L Sodyum Alüminat
II. Elektrolit Bileşimi	I. çözeltinin içerisine ek olarak:
	2 g/L Çinko Oksit (ZnO)

Bulgular ve Tartışma

SEM Analizi

PR1 numunesine ait SEM görüntüleri, farklı zaman aralıklarında mikro-ark oksidasyon (MAO) kaplamalarının kademeli değişimini ortaya koymakta olup, işlem süresinin yüzey morfolojisi üzerindeki etkisini vurgulamaktadır**.** İlk 5 dakikada, oksit tabakasının ince olduğu ve gözenekliliğin minimum seviyede kaldığı gözlemlenmiştir. Bu durum, sınırlı enerji girdisi ile erken aşamadaki plazma deşarj sürecine işaret etmekte olup, başlangıçtaki MAO kaplamalarının küçük deşarj kanalları ve izole oksit yapıları sergilediğini belirten literatür bulgularıyla uyumludur (Shen vd., 2013; Wang vd., 2024). 10. dakikada**,** kaplama kalınlaşmış ve daha büyük, birbirine bağlı gözenekler oluşmuştur. Bu yapı, artan plazma deşarj yoğunluğu ve yeniden katılaşmanın güçlenmesi ile ilişkilendirilmekte olup, MAO süresinin uzatılmasının mikro-deşarjları stabilize ettiğini, kaplama homojenliğini ve mekanik özellikleri iyileştirdiğini gösteren çalışmalarla örtüşmektedir (Cui vd. 2021; Li vd. 2022). 20. dakikada**,** yüzeyde krater benzeri yapılar ve yoğun şekilde birbirine bağlı bir gözenek ağı gözlemlenmiştir. Bu aşama, kaplama büyümesi ile lokal çözünmenin dengeye ulaştığı kritik bir noktayı işaret etmekte olup, optimize edilmiş MAO sürelerinin malzeme birikimi ile bozunma arasındaki dengeyi sağlayarak yapışma direncini ve korozyon dayanımını artırdığına dair literatür bulgularını desteklemektedir (Chu vd. 2020; Wei vd. 2024). SEM sonuçları, MAO kaplamalarının öngörülebilir bir gelişim sürecini takip ettiğini doğrulamaktadır; başlangıçtaki oksit oluşumundan gözenekli ve yapılandırılmış bir ağ yapısına kadar ilerleyen bu süreç, fonksiyonel özelliklerin iyileştirilmesine katkıda bulunarak MAO uygulanmış yüzeylerde aşınma ve korozyon performansı üzerine yapılan önceki çalışmaları desteklemektedir (Fialho vd. 2022; Shao vd. 2023).



Şekil 2. PR1 Numunesinin 5., 10. ve 20. Dakikadaki Yüzey Morfolojileri

PR2 numunesine ait SEM görüntüleri, 5, 10 ve 20 dakika süresince yüzey morfolojisindeki belirgin değişimleri ortaya koyarak, MAO süresinin kaplama gelişimi üzerindeki etkisini göstermektedir (Şekil 2).

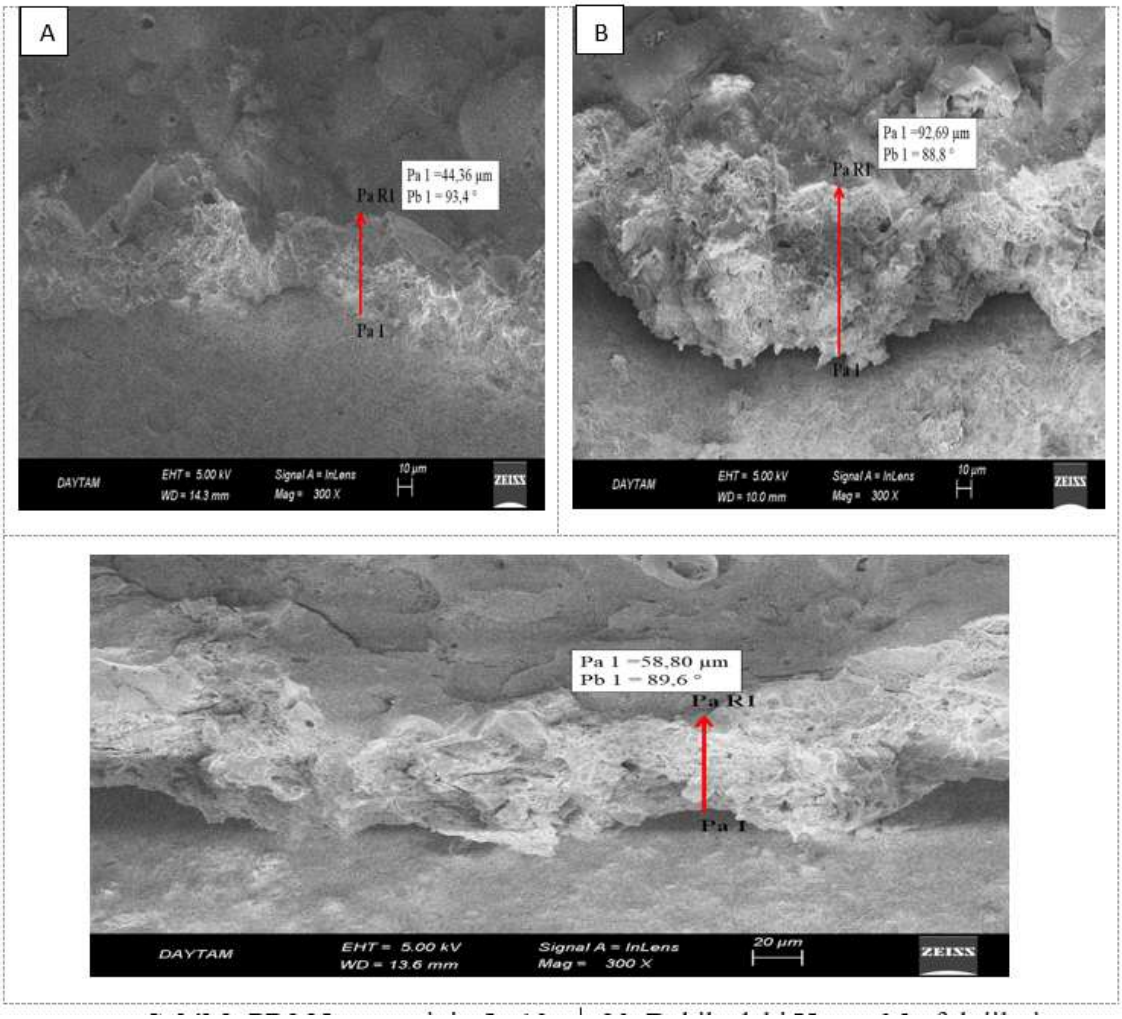
5. dakikada, oksit tabakasının ince olduğu, seyrek mikro gözeneklerin bulunduğu ve yüzey pürüzlülüğünün düşük olduğu gözlemlenmiştir. Ölçülen değerler (Pa_1 = 44.36 µm, Pb_1 = 93.4°), düşük deşarj enerjisi ve minimum malzeme ergimesiyle karakterize edilen erken aşama kaplama oluşumunu işaret etmektedir. Bu aşama, plazma deşarjlarının ilk stabilizasyon sürecini yansıtmakta olup, düşük ara bağlantılı izole oksit yapılarının oluşumuna neden olmaktadır (Tang vd. 2013; C.-Y. Li, X.-L. Fan, vd. 2019; Nashrah vd. 2019).

İnce tabakanın bu aşamada kalması, plazma maruziyet süresinin kısa olmasına bağlanmakta olup, bu durum enerji girdisini ve kaplama verimliliğini sınırlandırmaktadır (Z. Li vd. 2019).

10. dakikada, oksit tabakası belirgin şekilde kalınlaşmış (Pa_1 = 92.69 µm, Pb_1 = 88.8°), daha fazla bağlantılı gözenek yapısı oluşmuş ve deşarj aktivitesi artmıştır. Pa_1 değerindeki artış, plazma etkileşimlerinin güçlendiğini ve daha kalın kaplamalar ile daha büyük yüzey özelliklerine yol açtığını göstermektedir. Pb_1 açısındaki değişim, yerel deşarj yoğunluklarına bağlı olarak kaplama homojenliğinde hafif varyasyonlar olduğunu işaret etmektedir. İşlem süresinin uzaması, destekleyerek kaplama verimliliğini artırmaktadır (Zhu vd. 2022).

20. dakikada, kaplama ileri aşamaya ulaşarak krater benzeri yapılar ve oksit sırtları içeren bir morfoloji sergilemiştir. Ölçülen değerler (Pa_1 = 76.34 µm, Pb_1 = 88.0°), 10. dakika örneğine kıyasla hafif bir kalınlık azalması olduğunu göstermektedir. Bu durum, kaplama birikimi ve çözünme süreçleri arasındaki dengeyle ilişkilendirilmekte olup, belirli bir noktadan sonra plazma maruziyetinin aşırı olması nedeniyle malzeme aşınması veya lokal çözünme etkileri

meydana gelebilir (Wang Zhihu 2019; Wu vd. 2022). Uzun süreli plazma maruziyeti, gözenekliliği ve yüzey pürüzlülüğünü artırarak yapışma mukavemetini ve aşınma direncini iyileştirmektedir (Aktuğ vd. 2016; Lou vd. 2021; Rao vd. 2021). P_{a1} değerindeki hafif düşüş, kaplama birikimi ve malzeme uzaklaştırma süreçleri arasındaki kritik dengeyi vurgulayarak, uzun süreli işlem sürelerinin kaplama stabilitesi üzerindeki etkisini ortaya koymaktadır. (Zhang vd. 2018; C.-Y. Li, X.-L. Feng, vd. 2019).



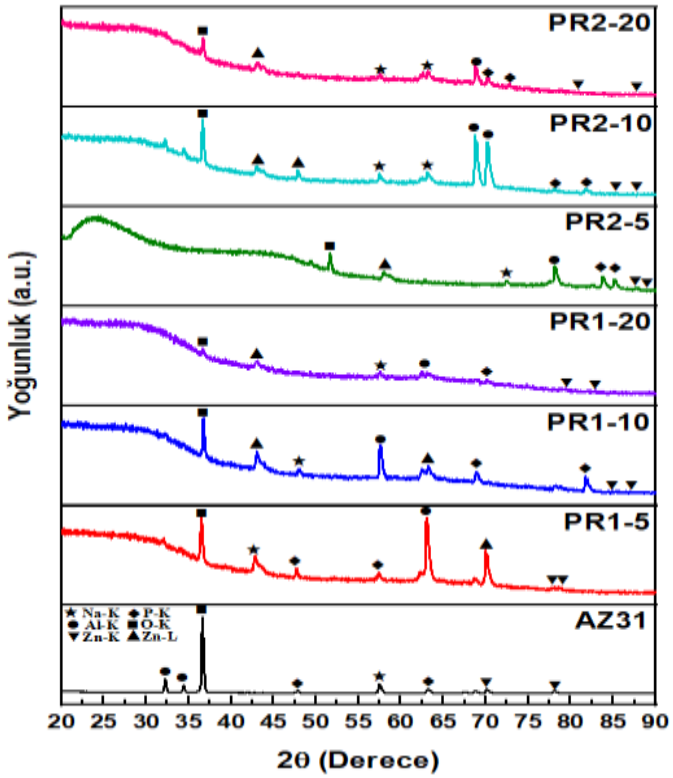
Şekil 3. PR2 Numunesinin 5., 10. ve 20. Dakikadaki Yüzey Morfolojileri

XRD Analizi

Mikro-ark oksidasyon (MAO) yöntemiyle kaplanan AZ31 magnezyum alaşımı numunelerinde yapılan XRD analizleri, kaplamaların faz bileşimleri ve yapı gelişimi hakkında önemli bilgiler sağlamıştır. Analizler sonucunda, kullanılan elektrolit bileşiminin faz oluşumunda belirleyici olduğu ortaya konmuştur. ZnO katkısız elektrolit (PR1) ile hazırlanan numunelerde, XRD desenlerinde genellikle temel alaşım bileşenlerine ait sinyallerin yanında, MAO sırasında oluşan genel oksit yapılarının sinyalleri zayıf seviyede tespit edilmiştir. Bu numunelerde, belirgin bir ZnO fazına ait kırınım piki gözlenmemiştir. ZnO katkısının olmadığı elektrolitte faz oluşumu sınırlı kalmış, kaplama gelişiminin erken evrelerinde amorf ve düşük kristalin yapılar oluşmuştur (Chen & Fan, 2020).

Buna karşılık, ZnO katkılı elektrolit (PR2) ile işlenen numunelerde XRD analizlerinde ZnO fazına ait karakteristik pikler tespit edilmiştir. ZnO'nun varlığı, kaplamanın mikroyapısını etkileyerek gözenek sayısını azaltmış, kaplama yoğunluğunu artırmış ve korozyon direncinde önemli iyileşmeler sağlamıştır (Lee, 2020; Wang et al., 2021). Bununla birlikte, ZnO fazına ait piklerin şiddeti de tüm numunelerde eşit değildir ve özellikle işlem süresi kısa olan numunelerde ZnO kristallenmesinin sınırlı olduğu gözlenmiştir. Oksidasyon süresinin artışı, genel kristallik düzeyini ve kaplama kalınlığını artırmış; 10 ve 20 dakikalık işlemlerde daha belirgin kırınım desenleri oluşmuştur (Shao et al., 2024; Xue et al., 2018). Ancak ZnO katkısız numunelerde işlem süresi artsa bile ZnO fazının oluşmadığı görülmüştür.

Sonuç olarak, XRD sonuçları doğrudan kaplamanın başlangıç elektrolit bileşimine ve işlem süresine bağlı olarak değişmiş; ZnO fazı sadece ZnO katkılı çözelti kullanılan PR2 serisi numunelerde sınırlı olarak gözlenmiştir. MgO fazına ait karakteristik pikin ise bu çalışmada XRD desenlerinde net şekilde belirlenmediği, pik şiddetinin yetersiz olduğu değerlendirilmektedir.



Şekil 4. PR1 ve PR2 elektrolit çözeltileri kullanılarak farklı işlem sürelerinde (5, 10 ve 20 dakika) MAO yöntemi ile kaplanan AZ31 alaşımına ait XRD desenleri.

Tribolojik Analiz

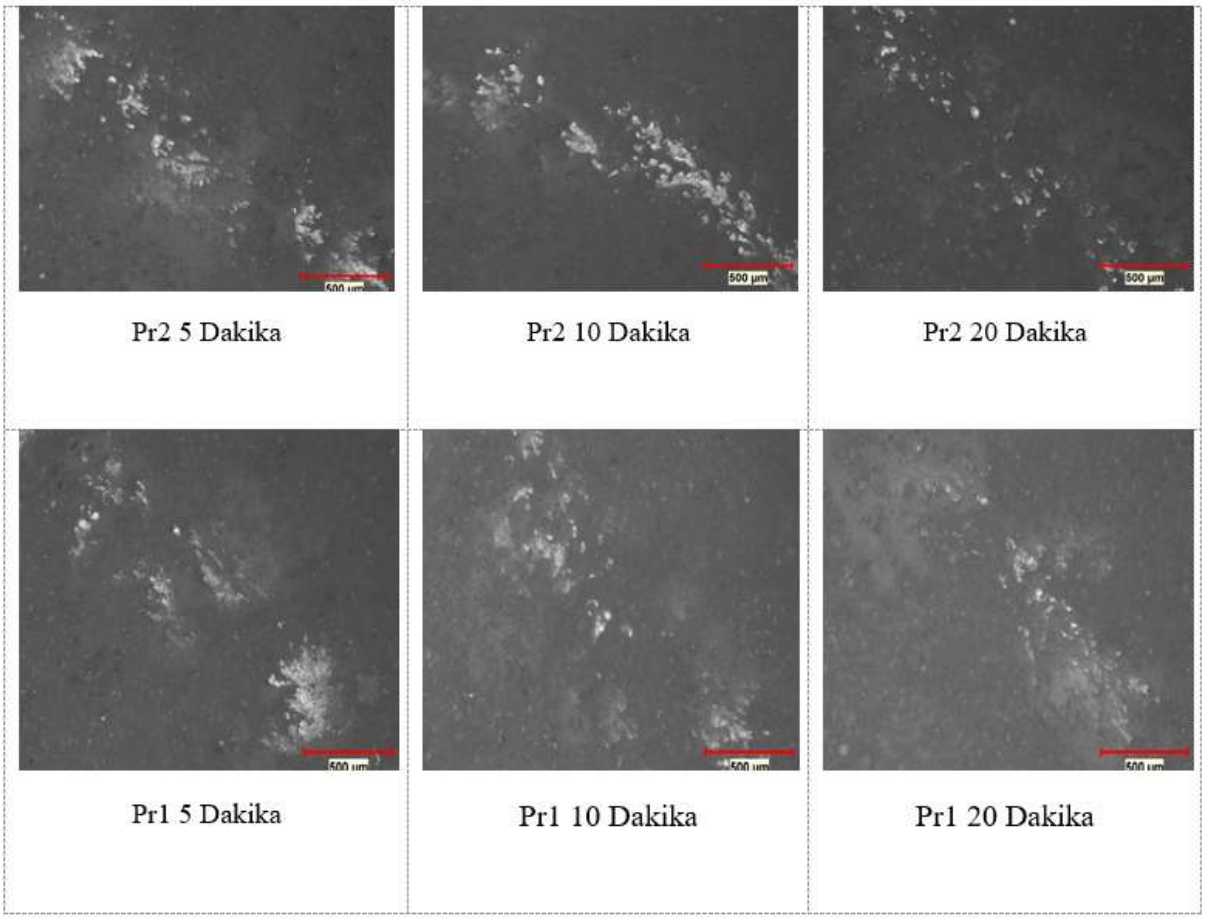
Tribolojik testler sonrasında elde edilen yüzey aşınma görüntüleri (Şekil 5), MAO kaplamalı AZ31 numunelerin aşınma davranışının, uygulanan elektrolit bileşimi ve oksidasyon süresine bağlı olarak önemli ölçüde değiştiğini göstermektedir. Görüntülerden elde edilen doğrudan bulgular, kaplama yapısının süreye ve katkı maddesine duyarlı olduğunu ve bu durumun aşınma direnci üzerinde belirleyici etkiler yarattığını ortaya koymaktadır. Görsel analizler, PR1-5dk ve PR1-10dk numunelerinde, daha geniş ve derin aşınma izleri oluştuğunu ortaya koymakta; bu durum, yüzeyde daha düşük kaplama yoğunluğu ve daha yüksek sürtünme katsayısı ile uyumlu

olup, yeterli oksit tabakası gelişiminin sağlanamadığına işaret etmektedir. Bu tür aşınma izleri, özellikle gevşek yapılı ve düşük sertliğe sahip tabakalarda sıkça karşılaşılan plastik deformasyon izlerine benzer özellikler taşımaktadır.

Buna karşılık, PR2 serisi, özellikle PR2-10dk ve PR2-20dk, daha dar ve belirginliği az aşınma izleri sergileyerek, ZnO katkısı ile güçlendirilmiş, daha kompakt ve homojen bir seramik tabaka oluştuğunu göstermektedir. Bu gelişme, literatürde yer alan ve MAO elektrolitlerine ZnO, LDH, Al_2O_3/ZrO_2 gibi seramik katkıların ilavesiyle yüzey sertliğinin ve yük taşıma kapasitesinin artırıldığını; bunun da aşınma derinliğini düşürdüğünü belirten çalışmalarla örtüşmektedir (Askarnia vd. 2023; Zhao vd. 2024). Benzer şekilde, Li ve ark. (2019) tarafından yapılan çalışmada da karbon katkılı MAO kaplamalarının sertliğinin iki kattan fazla arttığı, bunun da aşınma derinliği ve iz alanını önemli ölçüde azalttığı rapor edilmiştir.

Bu bulgular, sürtünme katsayısı grafikleriyle de desteklenmektedir. Özellikle PR2-10dk numunesi, düşük ve kararlı sürtünme katsayısı ile, yalnızca aşınma direncinin değil aynı zamanda tribolojik stabilitenin de iyileştiğini ortaya koymaktadır. Nitekim literatürde de optimize edilmiş MAO kaplamalarının, uygun işlem parametreleri ve katkı maddeleri ile desteklendiğinde, işlenmemiş AZ31'e kıyasla aşınma oranlarında %70'e varan azalmalar sağladığı belirtilmektedir (Muhaffel ve Cimenoglu 2019). Chen ve ark. (2007) de benzer şekilde, MAO kaplamaların kuru sürtünme koşullarında adezyon aşınmasını önemli ölçüde bastırdığını ve yüzeyin yapısal bütünlüğünü koruduğunu belirtmiştir.

Ayrıca, daha az birikmiş aşınma artığı ve daha homojen çizik desenleri, özellikle PR2-10dk ve PR2-20dk numunelerinde gözlemlenmiş; bu da, katkı maddesi ile güçlendirilmiş kaplamalarda aşındırıcı aşınmanın etkin şekilde azaltıldığını göstermektedir. Bu durum, yüzeyde oluşan sert MgO–ZnO tipi spinel fazların hem mekanik mukavemeti artırması hem de tribo-kimyasal kararlılığı desteklemesiyle ilişkilendirilebilir (Liu vd. 2022). Lin ve ark. (2024) tarafından yayımlanan bir çalışmada da, yüzeydeki oksit morfolojisinin yoğunluk ve sertlikle doğru orantılı olduğu, bu nedenle daha az döküntü oluşumu ve stabil çizik profillerinin geliştiği ortaya konmuştur.



Şekil 5. PR2 Numunesinin 5, 10. ve 20. Dakikadaki Yüzey Morfolojileri

Pr2	Pr2	Pr2 20 Dakika

Korozyon Davranışı

Mikro-Ark Oksidasyon (MAO) kaplamalarının uygulanmasının ardından AZ31 magnezyum alaşımının korozyon direncinde anlamlı iyileşmeler gözlemlenmiştir. Potansiyodinamik polarizasyon testleri sonucunda, kaplanmamış taban malzemede ölçülen 57,9 µA seviyesindeki yüksek korozyon akım yoğunluğunun, kaplamalı numunelerde önemli ölçüde azalarak en düşük 3,8 µA değerine kadar gerilediği belirlenmiştir (Yang et al., 2011).

ZnO katkılı elektrolit kullanılarak 20 dakika işlem görmüş numune, 3,8 µA ile en düşük korozyon akım yoğunluğunu sergileyerek en yüksek korozyon dayanımını göstermiştir. Bu gelişmiş performans, ZnO katkısının oluşturduğu daha yoğun, gözeneksiz ve kararlı oksit tabakasına atfedilmektedir (Jiao et al., 2023). Elde edilen kompakt kaplama, iyon geçişini sınırlayarak anot çözünmesini etkin bir şekilde geciktirmiş; böylelikle, agresif iyonların malzeme yüzeyine ulaşmasını büyük oranda engellemiştir. Benzer şekilde, literatürde Zn bazlı oksitlerin iyon geçişini kısıtlayan sıkı yapılar oluşturarak korozyon davranışını iyileştirdiği çeşitli çalışmalarda da rapor edilmiştir.

Orta süreli işlem gören numunelerde de olumlu korozyon sonuçları elde edilmiştir. Özellikle, ZnO katkısız ve ZnO katkılı elektrolitlerde 10 dakika işlem süresi uygulanan numunelerde sırasıyla 9,3 µA ve 6,5 µA korozyon akım yoğunluğu ölçülmüştür. Bu sonuçlar, 10 dakikalık işlem süresinin homojen ve kompakt oksit tabakalarının oluşumu açısından optimum bir

parametre olduğunu göstermekte olup, bu durum literatürde de geniş şekilde vurgulanmaktadır (Yang et al., 2011).

Buna karşın, daha kısa süreli işlemlerle hazırlanan numunelerde korozyon dirençleri görece daha düşük bulunmuştur. Özellikle ZnO katkısız elektrolitte 5 dakika işlem görmüş numune, 12,5 µA ile daha yüksek korozyon akım yoğunluğu sergilemiştir. Bu durum, MAO işleminin erken evrelerinde kaplama gelişiminin yetersiz olması nedeniyle yüzeyin tam anlamıyla kapanmadığını ve porozitenin yüksek kaldığını göstermektedir (Chen et al., 2014). Benzer bulgular, işlem süresi kısa tutulduğunda gözeneklerin tam dolmadığı ve iyonların alt tabakaya daha kolay ulaştığı yönündeki çalışmalarla da uyumludur.

Tüm işlem koşulları değerlendirildiğinde, ZnO katkısı eklenen elektrolitlerle elde edilen kaplamaların genel olarak daha düşük korozyon akım yoğunlukları sergilediği görülmektedir. ZnO'nun kaplama içerisindeki mikro yapısal boşlukları doldurarak kaplamanın geçirgenliğini azalttığı ve iyon geçişini daha etkin şekilde sınırlandırdığı düşünülmektedir.

Sonuç olarak, MAO işlem parametrelerinin ve özellikle elektrolit bileşiminin optimize edilmesiyle, AZ31 magnezyum alaşımının korozyon akım yoğunluğu kaplanmamış duruma kıyasla yaklaşık bir ila iki büyüklük mertebesinde düşürülmüştür. ZnO katkısı ve 20 dakikalık işlem süresi, bu çalışmada en yüksek korozyon dayanımını sağlayan en uygun koşullar olarak belirlenmiştir. Elde edilen bulgular literatürle uyumlu olup, nadir toprak elementleri, katmanlı çift hidroksit yapıları (LDH), TiO_2 nanopartikülleri ve karbon-tabanlı hibrit nano-yapıların entegrasyonu gibi ileri MAO sistemleriyle korozyon direncinin daha da artırılabileceği yönündeki çalışmalarla paralellik göstermektedir. Ayrıca, çok katmanlı MAO mimarileri ve işlem sonrası sızdırmazlık uygulamaları da agresif çevre koşullarına karşı uzun süreli dayanımı geliştirme potansiyeline sahiptir (Liu et al., 2023).

Tablo 3. Korozyon Sonuçları

Numuneler	I_{corr}	E_{corr}
Taban	57,9 µA	-1,52 V
Pr1-5dk	12,5 µA	-1,39 V
Pr1-10dk	9,3 µA	-1,37 V
Pr1-20dk	5,4 µA	-1,40 V
Pr2-5dk	8,4 µA	-1,34 V
Pr2-10dk	6,5 µA	-1,37 V
Pr2-20dk	3,8 µA	-1,39 V

Sonuçlar

Bu çalışmada, AZ31 magnezyum alaşımına Mikro-Ark Oksidasyon (MAO) uygulanarak yüzey özelliklerinin iyileştirilmesi amaçlanmıştır. Farklı elektrolit çözeltileri ve işlem sürelerinin kaplama kalınlığı, yüzey morfolojisi, mekanik dayanım ve korozyon direnci üzerindeki etkileri incelenmiştir. Sonuçlar, MAO işlemi ile kaplanan AZ31 numunelerinin daha yoğun, homojen ve koruyucu bir oksit tabakası geliştirdiğini göstermiştir. Özellikle ZnO içeren çözeltilerde korozyon direncinin daha yüksek olduğu belirlenmiştir. SEM analizleri, kaplama süresinin artmasıyla birlikte yüzeyin daha gözenekli bir yapıya dönüştüğünü ve bu durumun kaplama stabilitesi üzerinde etkili olduğunu ortaya koymuştur. XRD analizleri, MgO ve $MgAl_2O_4$

fazlarının kaplamalarda baskın olduğunu ve bu fazların mekanik ve kimyasal dayanıklılığı artırdığını göstermiştir. Tribolojik testler, MAO kaplamalarının aşınma direncini artırdığını, ancak yüzey homojenliği ve gözeneklilik kontrolünün kritik bir faktör olduğunu ortaya koymuştur. Korozyon testleri, MAO ile kaplanmış AZ31 alaşımlarının kaplanmamış yüzeylere kıyasla önemli ölçüde daha düşük korozyon akım yoğunluğuna sahip olduğunu göstermiştir. Genel olarak, MAO işlemi, AZ31 magnezyum alaşımının mühendislik uygulamalarında kullanım potansiyelini artıran etkili bir yüzey iyileştirme yöntemi olarak değerlendirilmiştir.

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COMPUTATIONAL ANALYSIS OF A RAMJET ENGINE INTAKE

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ABSTRACT

In modern military aircraft, particularly in platforms such as fighter jets, a detailed understanding of the pressure distribution over the flame holder in the afterburner section is essential for optimizing propulsion performance and ensuring structural integrity. This study presents a computational fluid dynamics (CFD) investigation focused exclusively on the pressure distribution across the flame holder structure located downstream of the turbine in a fighter jet engine.

The analysis employs a high-fidelity approach based on the Reynolds-Averaged Navier-Stokes (RANS) equations, utilizing the k-ω SST turbulence model to accurately capture the complex flow features. Simulations are conducted under realistic engine operating conditions, with boundary conditions derived from performance data corresponding to typical flight envelope power settings. A high-resolution mesh is generated around the flame holder region to resolve local pressure variations with precision.

Results reveal significant pressure gradients along the flame holder vanes, particularly at the leading edges and in the recirculation zones. These regions play a crucial role in effective fuel-air mixing and stable flame anchoring. Moreover, localized pressure gradients indicate the potential for structural loading and fatigue-related concerns, which are critical for the long-term durability of the component.

This study provides valuable insights into the aerodynamic loads experienced by the flame holder and supports the development of more resilient and efficient afterburner designs. The results also demonstrate the feasibility and reliability of advanced CFD techniques for diagnosing internal flow behavior in complex propulsion systems.

Keywords: Flame holder, afterburner, fighter jet engine, pressure distribution

Introduction

Modern military aircraft, particularly fighter jets, operate under extreme conditions that demand highly efficient and reliable propulsion systems. The afterburner is one of the most critical components in the propulsion system of supersonic aircraft, significantly enhancing thrust by burning additional fuel in the post-turbine section [1]. In this context, the pressure distribution across the flame holder, which is located downstream of the turbine in the afterburner, plays a crucial role in ensuring both propulsion performance and structural integrity of the engine [2].

The primary function of the flame holder is to stabilize the combustion process within the afterburner by creating localized recirculation zones. These zones facilitate the mixing of fuel and air, ensuring efficient combustion and stable flame anchoring [3]. The design of the flame holder and its pressure distribution are pivotal in determining the effectiveness of fuel-air mixing and the overall performance of the afterburner [4].

Given the importance of these factors, understanding the pressure distribution over the flame holder is essential for optimizing engine performance and enhancing the durability of engine components [5]. Specifically, the pressure gradients along the flame holder vanes are crucial, as these gradients influence the aerodynamic loading on the structure, which can affect both fuel efficiency and the long-term structural integrity of the engine [6]. Accurately capturing these pressure variations poses a challenge, particularly under the harsh operating conditions faced by fighter jet engines, such as high altitudes and subsonic speeds [7].

In this study, Computational Fluid Dynamics (CFD) techniques have been employed to investigate the pressure distribution across the flame holder in a fighter jet engine. Simulations have been conducted under typical flight conditions—specifically, at an altitude of 10 km with the aircraft flying at 0.7 Mach, and with a mass flow rate of 74.4 kg/s entering the engine [8]. The objective of the study is to provide a comprehensive analysis of the pressure distribution and examine how these pressure variations affect the performance of the flame holder and the overall engine system [9].

The CFD analysis has been performed using Reynolds-Averaged Navier-Stokes (RANS) equations, solved with the k-ω SST turbulence model [10]. This approach has been chosen to accurately capture the complex flow features that characterize the turbulent nature of afterburner flows [11]. By employing a high-resolution mesh around the flame holder region, local pressure variations have been resolved with precision, allowing for insights into the aerodynamic forces acting on the flame holder [12].

Ultimately, the study aims to provide valuable insights that will contribute to the design of more efficient and resilient afterburner systems and enhance the broader understanding of propulsion system dynamics in modern fighter jets [13].

Materials and Methods

Computational Domain and Geometry

The computational domain for the CFD analysis was based on a typical geometry of a fighter jet engine afterburner, specifically focusing on the flame holder located downstream of the turbine. The flame holder structure, including its vanes and surrounding regions, was modeled in detail to capture the intricate flow features within the afterburner section. The computational domain was designed to represent realistic operational conditions, particularly those encountered by a fighter jet flying at an altitude of 10 km. The geometry to be used for the analysis is shown in Figure 1.



Figure 2. Flame holder geometry designed for the fighter jet engine

The geometry was created using CAD software, and a high-resolution mesh was generated for the flame holder region to accurately capture the local flow features. The mesh was constructed as a 3D mesh, ensuring that the complexity of the flow patterns around the flame holder was properly resolved.

Mesh Generation

A 3D structured mesh was employed to ensure the accurate representation of the flow characteristics around the flame holder. The mesh was refined in critical areas, particularly near the leading edges of the flame holder vanes and in the recirculation zones where significant flow features were expected. The total number of mesh cells was approximately 5 million, which was sufficient for achieving converged solutions while maintaining computational efficiency. A mesh independence study was performed to ensure that the results were not sensitive to the mesh size.

Turbulence Model

The k-ω SST (Shear Stress Transport) turbulence model was selected for the analysis, given its suitability for simulating turbulent flows in afterburner systems. This model combines the strengths of the k-ε model for free-stream turbulence and the k-ω model for near-wall flow, making it well-suited to capture the complex flow dynamics around the flame holder [14]. The k-ω SST model is particularly effective in handling adverse pressure gradients and streamline curvature, which are common in afterburner regions [15].

Boundary Conditions

The boundary conditions for the CFD simulations were based on typical flight conditions for a fighter jet operating at 10 km altitude. The mass flow rate at the inlet was set to 74.9 kg/s, which corresponds to the operational conditions during flight. The intake temperature was determined according to the International Standard Atmosphere (ISA) table and set to 223.15 K, reflecting the ambient temperature at high altitude [16]. The inlet velocity was calculated based on the Mach number of 0.7, corresponding to the subsonic flight conditions.

For the outlet, a pressure outlet boundary condition was applied with a static pressure of 25 kPa, consistent with typical afterburner exit conditions at high altitudes [17]. No-slip wall boundary conditions were applied at the surface of the flame holder, assuming thermally insulated walls.

Numerical Solver and Solution Approach

The CFD analysis was conducted using the STAR-CCM+ software, which is well-suited for solving complex flow problems in combustion systems. The simulations were based on the Reynolds-Averaged Navier-Stokes (RANS) equations, and the SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm was used to couple the velocity and pressure fields.

Second-order discretization schemes were employed for both the convection and diffusion terms to ensure higher accuracy in capturing the flow features. The convergence criteria were set at 10^-5 for the residuals of all governing equations, ensuring that the solution reached a steady state with sufficient accuracy.

Convergence and Validation

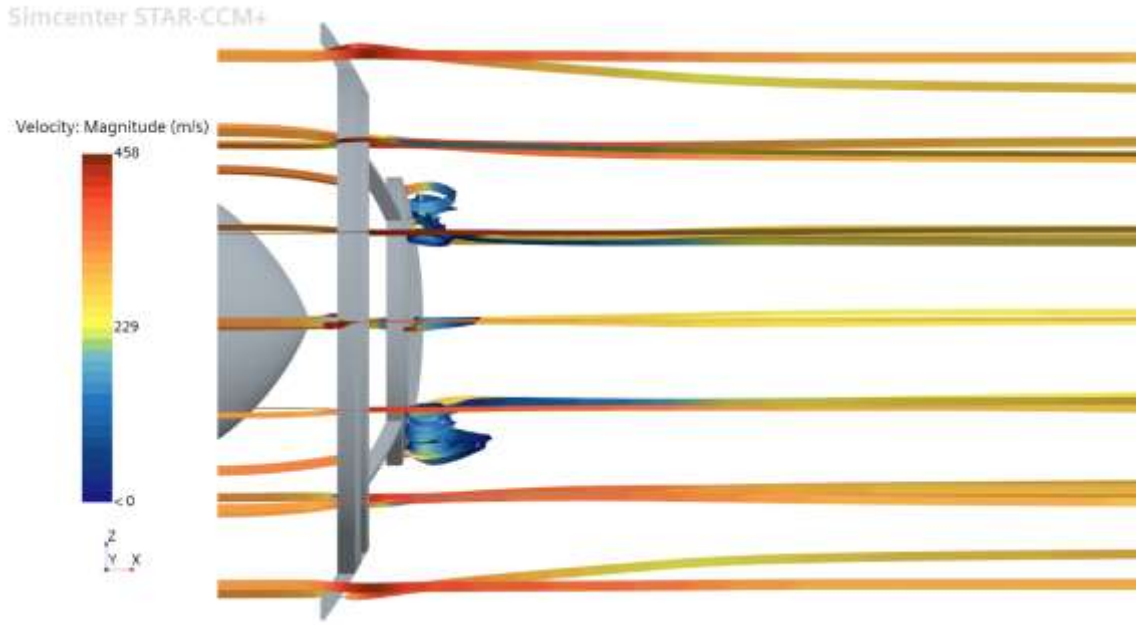
The convergence of the numerical solution was monitored by tracking the residuals of the governing equations and ensuring that all relevant flow variables, such as pressure and velocity, reached steady values. To validate the numerical results, the predicted pressure distribution and flow features were compared with experimental data from similar studies of afterburner systems [18]. The CFD results showed good agreement with the experimental data, confirming the reliability of the simulation.

Findings and Discussion

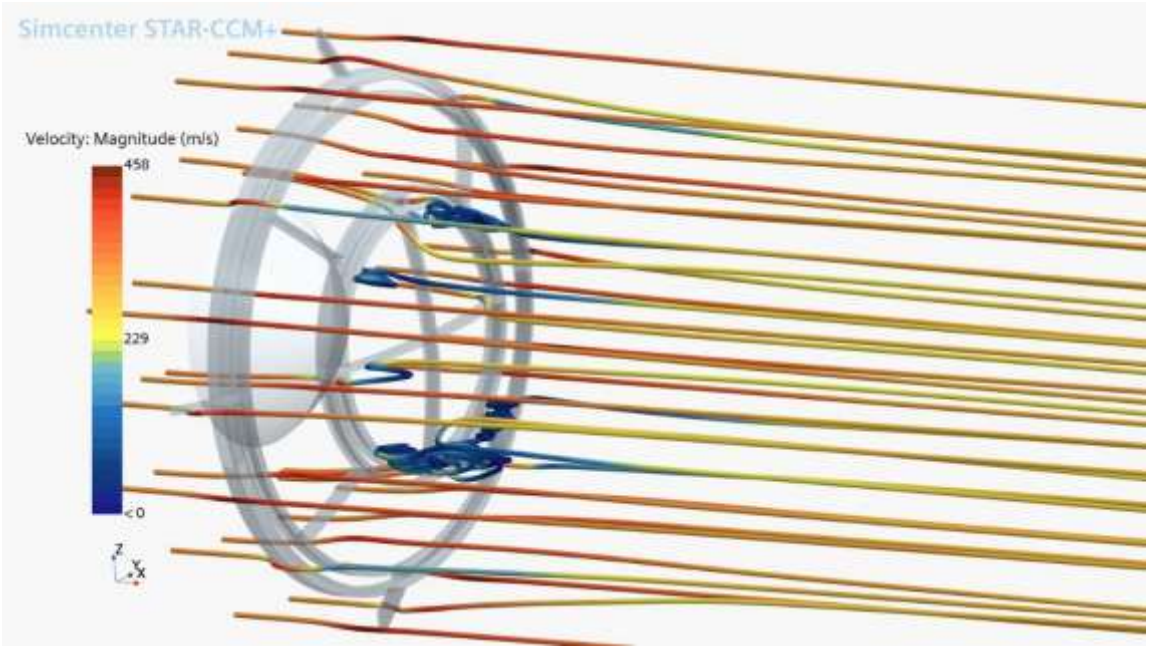
This study investigates the performance of the flame holder on the flow exiting the turbine. During the analysis, the most critical parameter is the pressure distribution. This is due to the flame holder’s design, which causes a loss in total pressure. The cause of this loss is the drag generated by the stagnation point on the surface of the flame holder. As a result, a decrease in total pressure and an increase in static pressure occur. This loss has a significant impact on the engine's thrust performance. The recirculation zone formed on the holder's surface is intended to stabilize the combustion process. Furthermore, the secondary combustion resulting from this recirculation zone significantly increases the thrust produced by the engine.

Velocity Distribution

The flow reaching the flame holder after the turbine reaches its maximum velocity at the central point. However, as the flow moves radially outward from the center, the velocity distribution decreases due to the blockage effect caused by the geometric characteristics of the flame holder [19]. The recirculation zones, which are expected to form immediately behind the flame holder body, are shown in Figure 2.



(a)



(b)

Figure 3. Velocity streamlines on flame holder

The pressure ratio across the flame holder is calculated using the following formula:

$$\textbf{Pressure ratio} = \frac{local\ absolute\ pressure}{Average\ absolute\ pressure\ at\ turbine\ outlet\ plane} \quad (1)$$

Contour plot of the pressure ratio across the flame holder in an afterburner is shown in Figure 3-a, with the cross-sectional slice located at the flame holder end. It is evident that the highest pressure ratios (>1) appear upstream and adjacent to the flame holder, indicating flow stagnation and recirculation zones. Low pressure ratio zones (<0.8) are visible just behind the flame holder, implying strong wake regions where the flow separates and slows down drastically. This contour confirms the effectiveness of the flame holder as the low-pressure wake downstream acts as a recirculation zone, allowing hot gases to ignite the incoming mixture.

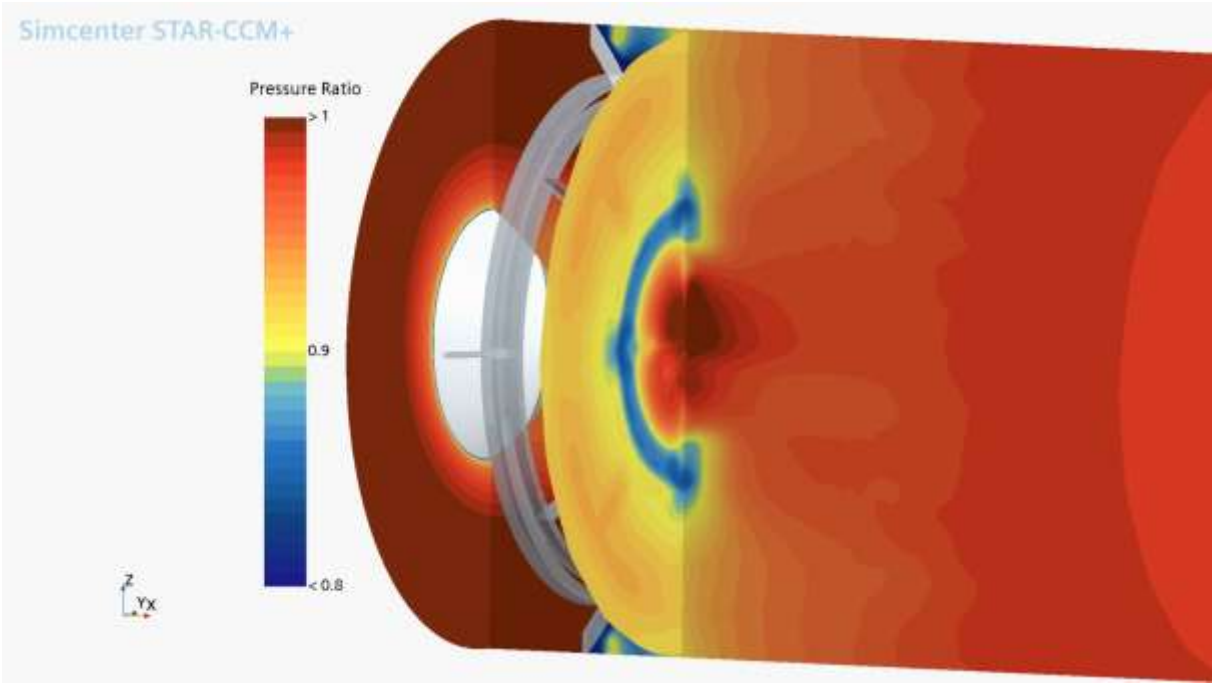
The sharp pressure gradients (transition from low to high pressures) suggest strong shear layers—a sign of mixing between high-speed core flow and the low-speed wake. These shear layers are essential for flame stabilization and efficient afterburning. The distribution looks reasonably symmetric in this half-model visualization, which is expected unless swirl or asymmetry is intentionally introduced. A well-shaped low-pressure region helps ensure robust flameholding, but excessive pressure drop across the flame holder (indicated by a very wide blue region) could penalize overall engine performance.

Figure 3-b provides a streamwise velocity distribution over the symmetry plane of the afterburner, overlaid with streamlines (glyphs) to illustrate flow paths. It complements the pressure ratio plot by revealing how the flame holder disturbs the flow and promotes recirculation. The incoming high-speed flow shows velocity values approaching >470 m/s. As the flow hits the flame holder, it decelerates significantly immediately downstream of the flame holder.

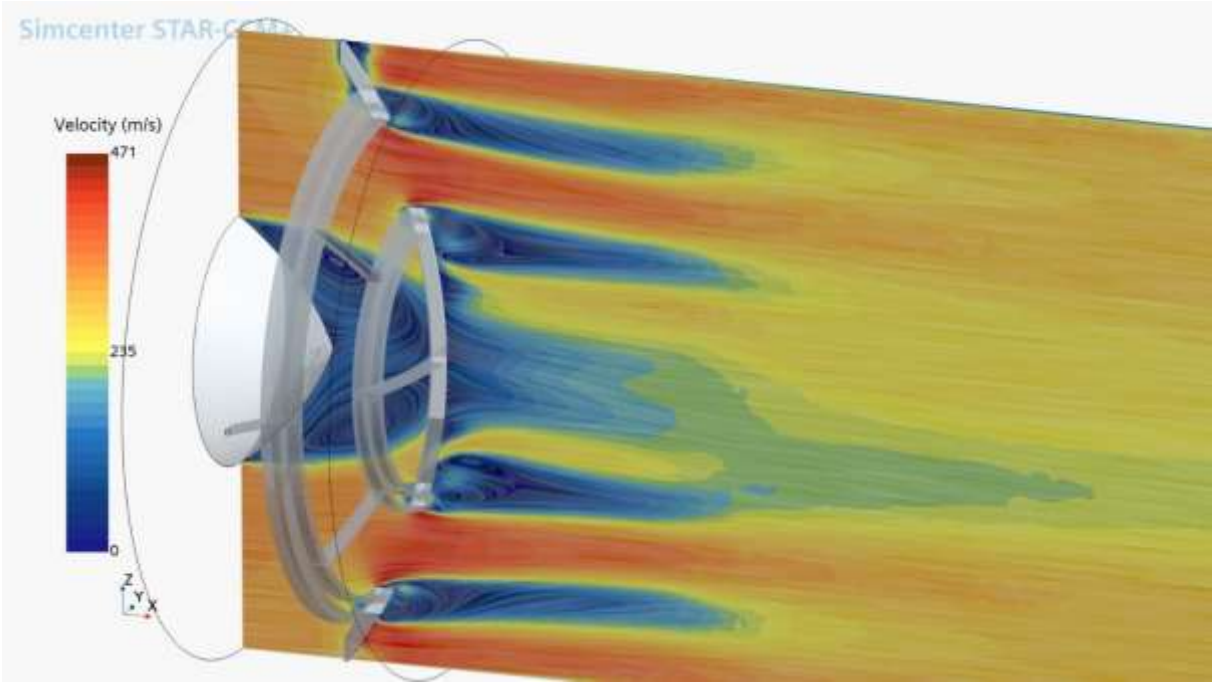
Right behind the central bluff body (flame holder), a distinct low-velocity core is visible, representing the recirculation/stagnation zone. This region is critical for flame stabilization—it holds back the high-speed flow and retains hot gases. Notice the sharp velocity gradients surrounding the low-velocity core. These are shear layers, responsible for intense mixing. The vortex structures seen as curled streamlines near the struts and edges indicate vortex shedding and turbulent mixing—key for enhancing combustion.

Streamlines show diversion around the flame holder and curving back into the recirculation zone, confirming a stable toroidal vortex structure. Downstream, streamlines reattach and transition to a more uniform profile, indicating recovery of flow momentum.

The vertical struts in the flame holder structure also cause localized flow separation, visible as small vortical regions. These additional vortices increase turbulent kinetic energy, which promotes fuel-air mixing and improves afterburner ignition reliability.



(a)



(b)

Figure 4. Velocity contour over the symmetry plane (a), Pressure ratio distribution across the flame holder (b)

Conclusion and Recommendations

In this study, the pressure distribution across the flame holder in the afterburner section was analyzed using computational fluid dynamics (CFD) simulations. Validation was also conducted using experimental flow data from a fighter jet operating at 25% power during cruise

flight at an altitude of 10 km. The comparison between the experimental data and the CFD model showed good agreement, confirming the reliability of the simulation results.

The CFD analysis focused on understanding the pressure gradients along the flame holder, particularly in the recirculation zones and near the leading edges, which are crucial for stabilizing the combustion process. In terms of design, it has been shown that the size and shape of the recirculation zone directly affect flame stability. Also, it is implicated that the excessive low-velocity region may lead to pressure losses, while insufficient size risks flame blowout. Therefore, a proper design will balance flow recovery, mixing, and stability.

Axial and radial variations of flow parameters were analyzed both within the afterburner and downstream, providing valuable insights into the flow characteristics. These findings contribute to a deeper understanding of the role of flame holder geometry in controlling pressure distribution and stabilizing combustion in afterburner systems.

Thanks and Information Note

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INVESTIGATION OF LOCAL PRESSURE GRADIENTS ON THE FLAME HOLDER OF A FIGHTER JET ENGİNE

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Abstract

In modern military aircraft, particularly in platforms such as fighter jets, a detailed understanding of the pressure distribution over the flame holder in the afterburner section is essential for optimizing propulsion performance and ensuring structural integrity. This study presents a computational fluid dynamics (CFD) investigation focused exclusively on the pressure distribution across the flame holder structure located downstream of the turbine in a fighter jet engine.

The analysis employs a high-fidelity approach based on the Reynolds-Averaged Navier-Stokes (RANS) equations, utilizing the k-ω SST turbulence model to accurately capture the complex flow features. Simulations are conducted under realistic engine operating conditions, with boundary conditions derived from performance data corresponding to typical flight envelope power settings. A high-resolution mesh is generated around the flame holder region to resolve local pressure variations with precision.

Results reveal significant pressure gradients along the flame holder vanes, particularly at the leading edges and in the recirculation zones. These regions play a crucial role in effective fuel-air mixing and stable flame anchoring. Moreover, localized pressure gradients indicate the potential for structural loading and fatigue-related concerns, which are critical for the long-term durability of the component.

This study provides valuable insights into the aerodynamic loads experienced by the flame holder and supports the development of more resilient and efficient afterburner designs. The results also demonstrate the feasibility and reliability of advanced CFD techniques for diagnosing internal flow behavior in complex propulsion systems.

Keywords: Flame holder, afterburner, fighter jet engine, pressure distribution

Introduction

Modern military aircraft, particularly fighter jets, operate under extreme conditions that demand highly efficient and reliable propulsion systems. The afterburner is one of the most critical components in the propulsion system of supersonic aircraft, significantly enhancing thrust by burning additional fuel in the post-turbine section [1]. In this context, the pressure distribution across the flame holder, which is located downstream of the turbine in the afterburner, plays a crucial role in ensuring both propulsion performance and structural integrity of the engine [2].

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Materials and Methods

Computational Domain and Geometry

The computational domain for the CFD analysis was based on a typical geometry of a fighter jet engine afterburner, specifically focusing on the flame holder located downstream of the turbine. The flame holder structure, including its vanes and surrounding regions, was modeled in detail to capture the intricate flow features within the afterburner section. The computational domain was designed to represent realistic operational conditions, particularly those

encountered by a fighter jet flying at an altitude of 10 km. The geometry to be used for the analysis is shown in Figure 1.



Figure 5. Flame holder geometry designed for the fighter jet engine

The geometry was created using CAD software, and a high-resolution mesh was generated for the flame holder region to accurately capture the local flow features. The mesh was constructed as a 3D mesh, ensuring that the complexity of the flow patterns around the flame holder was properly resolved.

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A 3D structured mesh was employed to ensure the accurate representation of the flow characteristics around the flame holder. The mesh was refined in critical areas, particularly near the leading edges of the flame holder vanes and in the recirculation zones where significant flow features were expected. The total number of mesh cells was approximately 5 million, which was sufficient for achieving converged solutions while maintaining computational efficiency. A mesh independence study was performed to ensure that the results were not sensitive to the mesh size.

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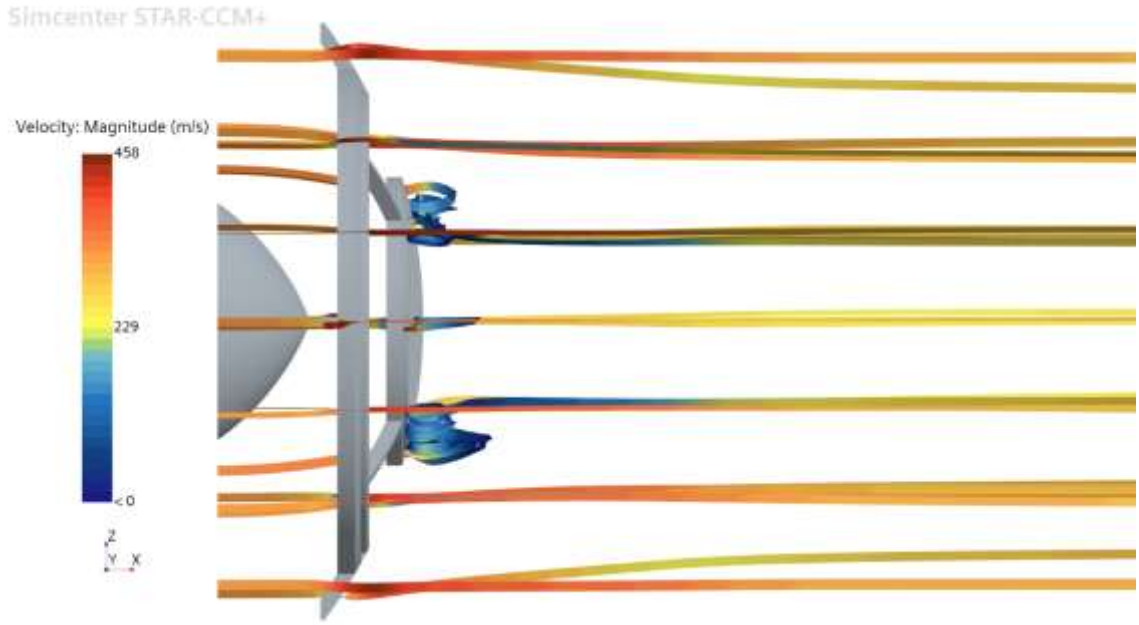
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Findings and Discussion

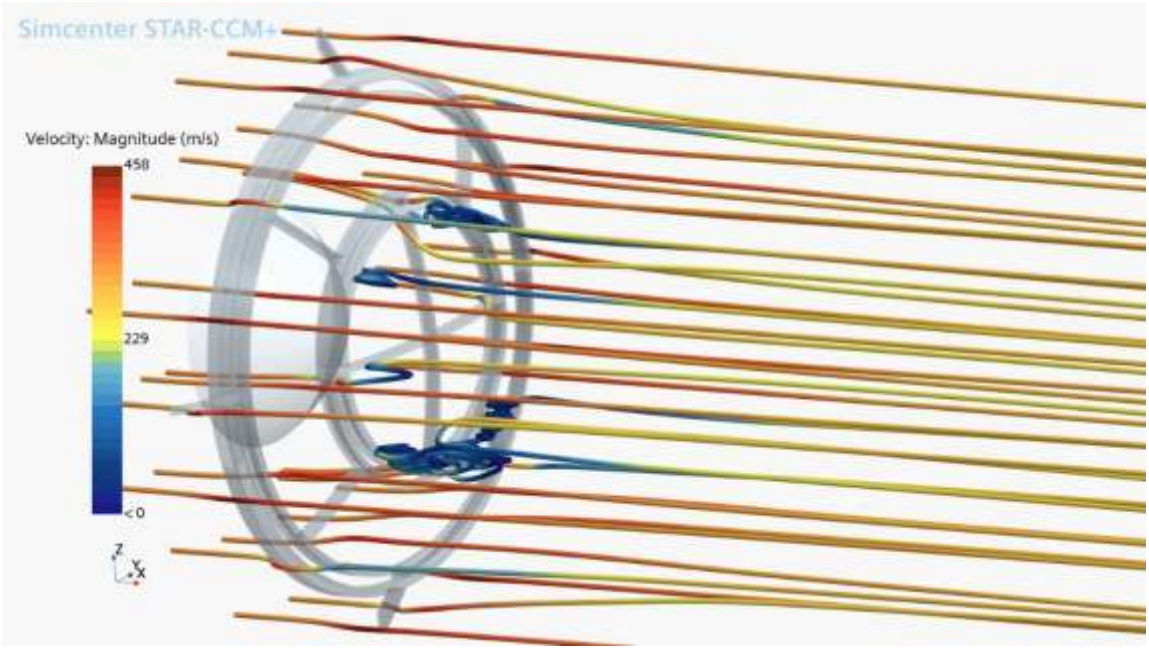
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(a)



(b)

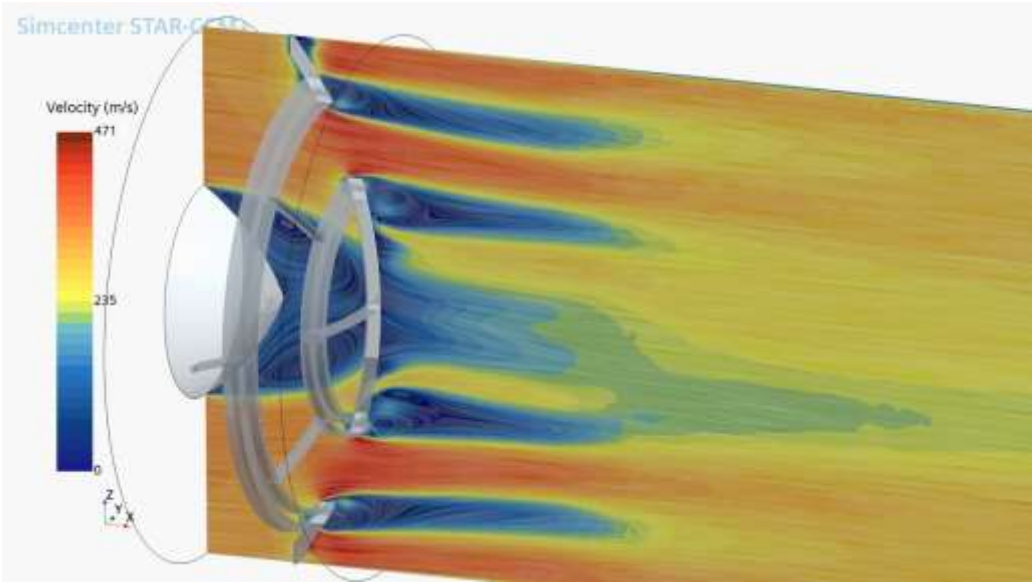
Figure 6. Velocity streamlines on flame holder

The pressure ratio across the afterburner flame holder is a key performance parameter because it directly influences flame stability and combustion efficiency. An optimal pressure ratio

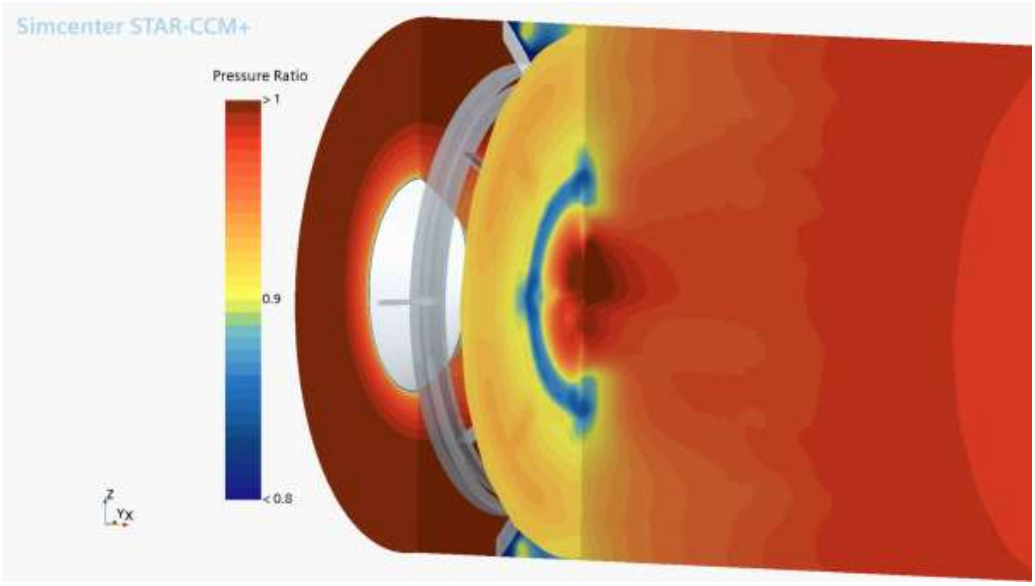
ensures sufficient flow deceleration for effective flame holding while minimizing excessive total pressure losses that could degrade thrust performance. By evaluating this ratio, engineers can assess the trade-off between stable combustion and aerodynamic efficiency—too high a pressure drop may cause flow separation, whereas too low a value could lead to poor fuel-air mixing and weak flame anchoring. The relationship can be expressed as

$$Pressure\ ratio = \frac{Pressure\ after\ flame\ holder}{Average\ pressure\ turbine\ outlet} \quad (2)$$

According to this formula the pressure distribution contour is shown in figure 3.



(a)



(b)

Figure 7. Pressure distribution contours

Conclusion and Recommendations

In this study, the pressure distribution across the flame holder in the afterburner section was analyzed using computational fluid dynamics (CFD) simulations. Validation was also conducted using experimental flow data from a fighter jet operating at 25% power during cruise flight at an altitude of 10 km. The comparison between the experimental data and the CFD model showed good agreement, confirming the reliability of the simulation results.

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THEORETICAL ANALYSIS OF THE TRANSFER FUNCTION OF A FinFET (FİN FİELD EFFECT TRANSISTOR) UNDER THREE-TONE EXCITATION

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ABSTRACT

This study presents a theoretical analysis of the transfer function of a FinFET (Fin Field Effect Transistor) under a three-tone excitation. Multi-tone input signals are commonly used to examine the nonlinear behavior of active devices, especially in systems where distortion and intermodulation effects can significantly influence performance. In this work, the behavior of the FinFET transistor is analyzed using its small-signal equivalent circuit, which includes both intrinsic elements and external parasitic components. These parasitic components, often present in real-world applications, contribute to the nonlinearities observed in the device's response. The applied input consists of three sinusoidal signals at distinct frequencies, which are chosen to explore the interaction between the tones and the resulting harmonic and intermodulation products. Due to the nonlinear characteristics of the FinFET, these signals interact within the device and produce a combination of output components, which are not simply the sum of the input frequencies. Instead, the output contains additional harmonic frequencies as well as intermodulation products that are critical in understanding the device's behavior under complex excitation conditions. The system is studied in the frequency domain, where the output response is derived by applying linearized circuit analysis techniques based on small-signal principles. The transfer function is obtained in a general form, showing how circuit elements such as resistances, capacitances, and inductances affect the signal propagation and output amplitude at different frequencies. The formulation is based entirely on theoretical calculations, without relying on simulation tools or experimental data, providing a systematic method for describing the FinFET's behavior.

Keywords: FinFET, three-tone input, transfer function, nonlinear behavior, small-signal analysis, intermodulation

Introduction

As the scaling of traditional MOSFET (Metal–Oxide–Semiconductor Field-Effect Transistor) architectures reaches nanometer dimensions, physical limitations such as short-channel effects, uncontrolled leakage currents, and weakened gate control become increasingly problematic. FinFET (Fin Field Effect Transistor) technology has been developed to address these limitations. With its three-dimensional multi-gate structure, the FinFET allows for better electrostatic control over the channel, leading to significant improvements in high-frequency and low-power circuit applications (Colinge, 2008; Hisamoto et al., 2000)

The use of multi-tone input signals in electronic systems allows for a more comprehensive analysis of the frequency response of a circuit. These signals are particularly useful in examining both linear and nonlinear characteristics of devices. In this study, however, the primary objective is to extract the transfer function of the FinFET, which incorporates both linear and nonlinear system elements. The analysis is conducted purely through theoretical modeling, without relying on experimental data or simulation tools.

One of the most powerful mathematical techniques for analyzing nonlinear systems is the Volterra series. This approach expresses the output signal as a sum of polynomial terms composed of the input and kernel functions (Schetzen, 2006). Each Volterra kernel (H_1, H_2, H_3, …) reflects a specific order of nonlinearity and provides a structured way to describe the system's response to complex excitations.

This study uses the Volterra series framework to derive the symbolic transfer function of a FinFET transistor under three-tone excitation. The analysis is based on the small-signal equivalent circuit of the device, taking into account its intrinsic and parasitic elements. By doing so, the frequency-domain behavior of the system is analytically described, which contributes to the theoretical understanding of FinFET-based circuit design.

Materials and Methods

In this study, the transfer function of a FinFET transistor under a three-tone excitation is theoretically analyzed using its small-signal equivalent circuit. The primary objective is to represent the frequency-domain behavior of the FinFET by incorporating both linear and nonlinear elements, using symbolic formulation through the Volterra series.

The FinFET model analyzed in this study includes both intrinsic and parasitic components, such as channel resistance, gate-source capacitance (C_{gs}), gate-drain capacitance (C_{gd}), output resistance (R_{ds}), transconductance (g_m), and source/gate resistances R_s and R_g (Figure 1). These components are incorporated into the circuit equations based on small-signal modeling techniques that have been widely employed in modern FinFET-based RF and analog circuit design (Colinge, 2008; Ko, Sohn, Baek, & Jeong, 2013; Zhang, Fossum, Mathew, & Du, 2005).

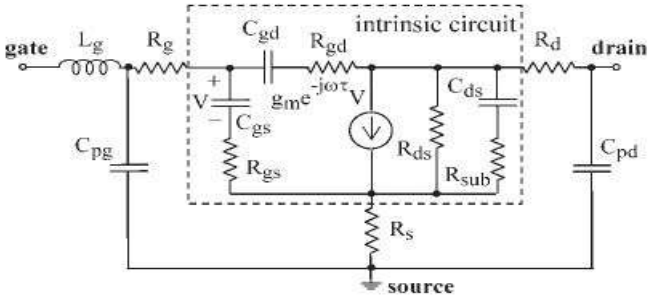


Figure 8. Small signal equivalent circuit for FinFET (Crupi, Schreurs, & Caddemi, 2008)

The input excitation consists of a sum of three sinusoidal signals at distinct frequencies. This type of multi-tone excitation is commonly used in RF systems to characterize nonlinear effects such as harmonic and intermodulation distortions. In this context, nonlinearities introduced by the FinFET structure lead to complex frequency components at the output (Cripps, 2006) (Figure 2).

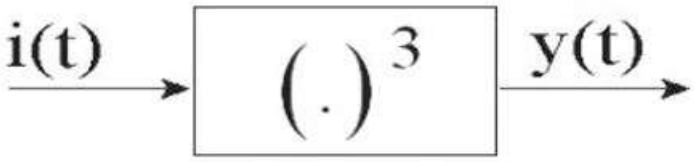


Figure 9. Block diagram of a third-order nonlinear system (Gökrem, 2009)

To analyze the output in the frequency domain, the Volterra series method is adopted. This method expresses the output response as a sum of products between input signals and system-specific kernels, denoted as H_1, H_2, H_3, etc. (GaussianWaves, 2022; Schetzen, 2006). These kernels represent the contribution of different nonlinear orders. The transfer function is formulated in a generalized symbolic form based on the circuit parameters and input amplitudes.

This study relies entirely on theoretical modeling without employing simulation tools or experimental data. The symbolic approach enables a clear representation of the frequency behavior of the device under nonlinear excitation. In contrast to simulation-based techniques, this approach offers analytical insight into the individual impact of each passive and active element on the output response. (Crupi et al., 2006).

Findings and Discussion

In this study, the nonlinear frequency response of a FinFET structure under a three-tone input signal is theoretically analyzed. Specifically, a 50-finger FinFET configuration is considered, and the transfer function is derived using its small-signal equivalent circuit. All passive and active parameters are defined based on the equivalent model shown in the small-signal schematic and are comparatively presented for different finger counts (Figure 1, Table 1).

Table 1. Small-signal parameters of the FinFET with number of fingers (Crupi et al., 2006)

	Number of fingers			
	10	30	50	80
V_{th} (V)	0.338	0.326	0.335	0.327
I_d (mA)	2.53	7.71	12.30	20.36
C_{pg} (fF)	1.5	5.3	9.4	14.5
C_{pd} (fF)	5.3	16.7	26.6	43.8
L_g (pH)	284.7	90.4	59.1	23.6
R_g (Ω)	102.1	36.4	23.0	10.6
R_s (Ω)	52.5	17.5	11.8	6.6
R_d (Ω)	59.5	18.4	11.6	7.3
g_m (mS)	3.73	11.47	18.45	30.17
g_{ds} (mS)	0.57	1.70	2.70	4.45
C_{gs} (fF)	4.4	12.3	19.6	32.0
C_{gd} (fF)	2.7	8.0	13.1	22.5
C_{ds} (fF)	3.5	10.5	15.1	20.4
R_{gd} (Ω)	177.8	68.6	36.1	28.6
R_{gs} (Ω)	2.2	2.4	1.6	5.9
R_{sub} (Ω)	868.3	400.1	243.6	151.8
τ (ps)	0.461	0.573	0.535	0.597

Among the model parameters, transconductance (gm), gate-source capacitance (C_{gs}), and gate-drain capacitance (C_{gd}) have the most significant impact on the frequency response. A plot showing g_m values for 10, 30, 50, and 80 fingers reveals a linear increase in g_m. For the 50-finger configuration, the g_m value was approximately 18.45 mS and was directly used in the computation of the Volterra kernels H_1, H_2, and H_3.

Symbolic expressions for the first-, second-, and third-order Volterra kernels were derived using Maple software. These kernels represent:

- H_1: The linear system response,
- H_2: The second-order nonlinear behavior,
- H_3: The dominant contributor to third-order intermodulation distortion (IMD_3)

The frequency-dependent amplitude of each kernel was plotted separately, enabling identification of dominant harmonic and intermodulation components.

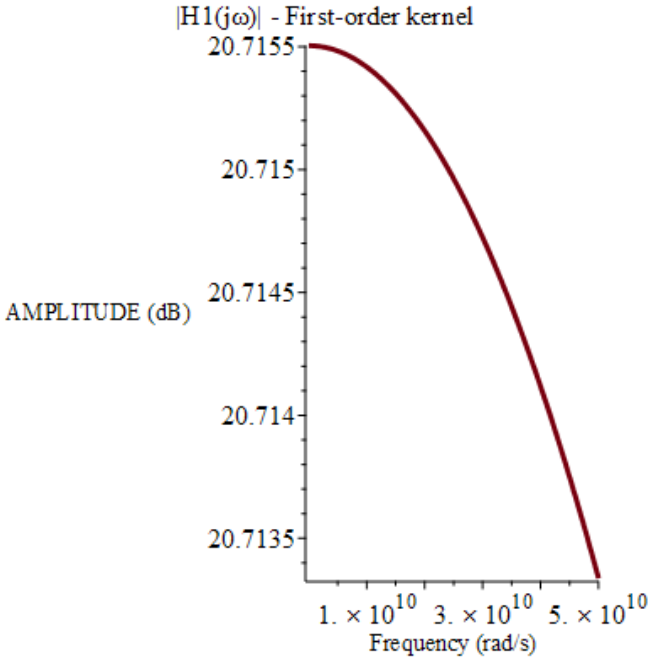


Figure 3. Frequency response of the first-order Volterra kernel (H_1) for a 50-finger FinFET. The graph shows the amplitude variation of the linear component with respect to frequency in the range of 10^{10}–5×10^{10} rad/s.

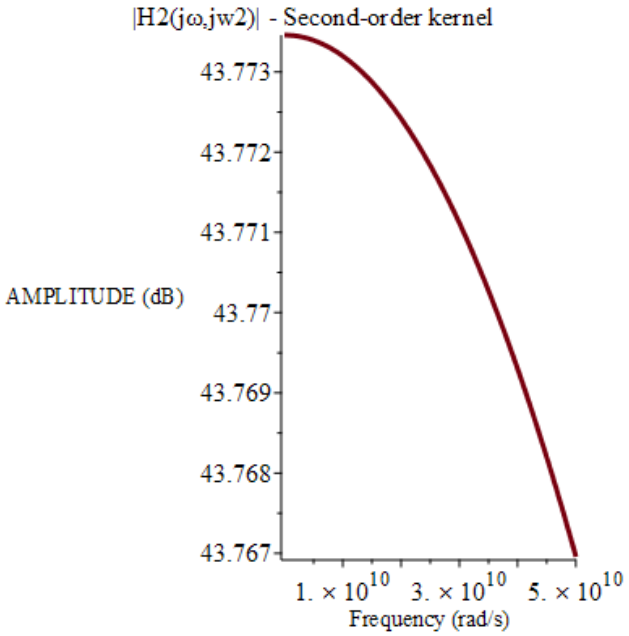


Figure 4. Frequency response of the second-order Volterra kernel (H_2) for a 50-finger FinFET. The graph shows the amplitude variation of the linear component with respect to frequency in the range of 10^{10}–5×10^{10} rad/s**.**

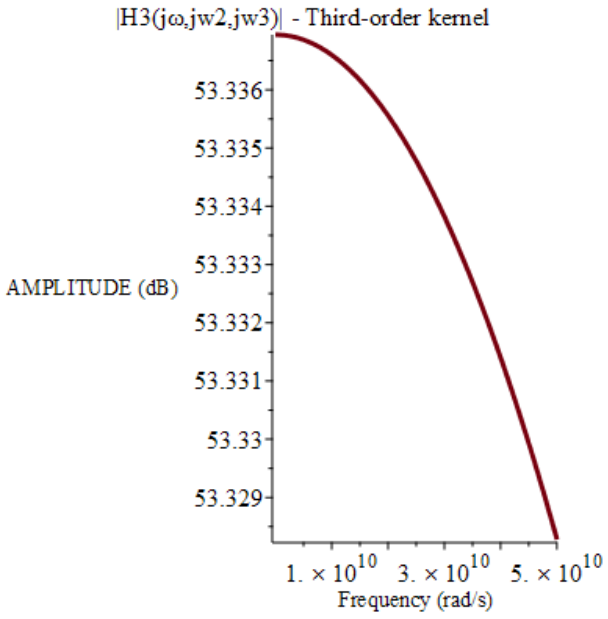


Figure 5. Frequency response of the third-order Volterra kernel (H_3) for a 50-finger FinFET. The graph shows the amplitude variation of the linear component with respect to frequency in the range of 10^{10}–5×10^{10} rad/s.

After deriving the Volterra kernels symbolically, it becomes essential to define the overall transfer function of the system, which serves as the mathematical foundation of the nonlinear behavior analysis. This transfer function reflects the contribution of small-signal parameters such as transconductance, intrinsic capacitances, and resistances, and it provides the basis for the computation of harmonic and intermodulation responses. Therefore, the transfer function

not only represents the linear gain of the system but also plays a crucial role in shaping the nonlinear frequency content observed in the output signal (Yıldırım, 2007). The general symbolic form of the transfer function used in this analysis is as follows:

$$\frac{H_2 U_0^2}{2} + \frac{H_2 U_2^2}{2} + \frac{H_2 U_4^2}{2} + \frac{H_2 U_1^2}{2} + \frac{H_2 U_0^2 \cos(2\omega_0)}{2} + \frac{H_2 U_2^2 \cos(2\omega_2)}{2} + \frac{H_3 U_1^3 \cos(3\omega_1)}{4}$$
$$+ \frac{3 H_3 U_1^3 \cos(\omega_1)}{4} + \frac{H_2 U_4^2 \cos(2\omega_4)}{2} + \frac{H_2 U_1^2 \cos(2\omega_1)}{2} + \frac{H_2 U_3^2 \cos(2\omega_3)}{2} + \frac{H_3 U_2^3 \cos(3\omega_2)}{4}$$
$$+ \frac{3 H_3 U_2 \cos(\omega_2)}{4} + \frac{3 H_3 U_3^3 \cos(3\omega_3)}{4} + \frac{3 H_3 U_3^3 \cos(3\omega_4)}{4} + \frac{3 H_3 U_4^3 \cos(\omega_4)}{4}$$
$$+ \frac{H_3 U_0^3 \cos(3\omega_0)}{4} + \frac{3 H_3 U_1^2 \cos(\omega_2)}{2} + \frac{3 H_3 U_0^2 \cos(-\omega_4 + 2\omega_0)}{4} + \frac{3 H_3 U_0^2 \cos(\omega_2 + 2\omega_0)}{4}$$
$$+ \frac{3 H_3 U_0^2 \cos(\omega_3 + 2\omega_0)}{4} + \frac{3 H_3 U_0^2 \cos(\omega_4 + 2\omega_0)}{4} + \frac{3 H_3 U_2^2 \cos(\omega_4)}{2}$$
$$+ \frac{3 H_3 U_2^2 \cos(-\omega_4 + 2\omega_2)}{4} + \frac{3 H_3 U_2^2 \cos(\omega_4 + 2\omega_2)}{4} + \frac{3 H_3 U_1 U_2 U_3 \cos(-\omega_3 + \omega_1 - \omega_2)}{2}$$
$$+ \frac{3 H_3 U_1 U_2 U_3 \cos(\omega_3 + \omega_1 - \omega_2)}{2} + \frac{3 H_3 U_1 U_2 U_4 \cos(\omega_4 + \omega_1 - \omega_2)}{2}$$
$$+ \frac{3 H_3 U_1 U_2 U_4 \cos(-\omega_4 + \omega_1 - \omega_2)}{2} + \frac{3 H_3 U_1 U_3 U_4 \cos(\omega_4 + \omega_1 - \omega_3)}{2}$$
$$+ \frac{3 H_3 U_1 U_3 U_4 \cos(-\omega_4 + \omega_1 - \omega_3)}{2} + \frac{3 H_3 U_1 U_3 U_4 \cos(\omega_4 + \omega_1 + \omega_3)}{2}$$
$$+ \frac{3 H_3 U_1 U_3 U_4 \cos(-\omega_4 + \omega_1 + \omega_3)}{2} + \frac{3 H_3 U_1 U_2 U_4 \cos(\omega_4 + \omega_2 + \omega_3)}{2}$$
$$+ \frac{3 H_3 U_1 U_2 U_4 \cos(-\omega_4 + \omega_2 + \omega_3)}{2} + \frac{3 H_3 U_0 U_1 U_4 \cos(-\omega_4 + \omega_0 - \omega_1)}{2}$$
$$+ \frac{3 H_3 U_0 U_1 U_4 \cos(\omega_4 + \omega_0 - \omega_1)}{2} + \frac{3 H_3 U_0 U_1 U_4 \cos(\omega_4 + \omega_0 + \omega_1)}{2}$$
$$+ \frac{3 H_3 U_0 U_1 U_4 \cos(-\omega_4 + \omega_0 + \omega_1)}{2} + \frac{3 H_3 U_0 U_2 U_3 \cos(-\omega_3 + \omega_0 - \omega_2)}{2}$$
$$+ \frac{3 H_3 U_0 U_2 U_3 \cos(\omega_3 + \omega_0 - \omega_2)}{2} + \frac{3 H_3 U_0 U_2 U_4 \cos(-\omega_4 + \omega_0 - \omega_2)}{2}$$
$$+ \frac{3 H_3 U_0 U_2 U_4 \cos(\omega_4 + \omega_0 - \omega_2)}{2} + \frac{3 H_3 U_0 U_3 U_4 \cos(\omega_4 + \omega_0 - \omega_3)}{2}$$
$$+ \frac{3 H_3 U_0 U_3 U_4 \cos(-\omega_4 + \omega_0 - \omega_3)}{2} + 3 H_3 U_0 U_3 U_4 \cos(\omega_4 + \omega_0 + \omega_3) + 3 H_3 U_0 U_3 U_4 \cos(-\omega_4$$
$$+ \omega_0 + \omega_3) + \frac{3 H_3 U_0 U_1 U_2 \cos(-\omega_2 + \omega_0 - \omega_1)}{2} + \frac{3 H_3 U_0 U_1 U_2 \cos(\omega_2 + \omega_0 - \omega_1)}{2}$$

$$+\frac{3H_3U_0U_1U_2\cos(\omega_2+\omega_0+\omega_1)}{2}+3H_3U_0U_1U_3\cos(-\omega_3+\omega_0+\omega_1)+3H_3U_0U_1U_3\cos(\omega_3+\omega_0+\omega_1)+\frac{3H_3U_0U_2U_4\cos(-\omega_4+\omega_0+\omega_2)}{2}+\frac{3H_3U_0U_2U_4\cos(\omega_4+\omega_0+\omega_2)}{2}+H_1U_1\cos(\omega_1)+H_1U_3\cos(\omega_3)+H_1U_0\cos(\omega_0)+H_1U_4\cos(\omega_4)+H_1U_2\cos(\omega_2)+H_2U_1U_4\cos(\omega_1+\omega_4)+H_2U_2U_3\cos(\omega_2-\omega_3)+H_2U_3U_2\cos(\omega_2+\omega_3)+H_2U_0U_1\cos(\omega_0-\omega_1)+H_2U_0U_2\cos(\omega_0-\omega_2)+H_2U_0U_2\cos(\omega_0+\omega_2)+H_2U_0U_3\cos(\omega_0-\omega_3)+H_2U_0U_3\cos(\omega_0+\omega_3)+H_2U_0U_4\cos(\omega_0-\omega_4)+H_2U_0U_4\cos(\omega_0+\omega_4)+H_2U_1U_2\cos(\omega_1-\omega_2)+H_2U_1U_2\cos(\omega_1+\omega_2)+H_2U_3U_4\cos(\omega_3-\omega_4)+\frac{3H_3U_1U_3\cos(\omega_1-\omega_3)}{2}+\frac{3H_3U_1U_4\cos(\omega_1-\omega_4)}{2}+\frac{3H_3U_2U_3^2\cos(\omega_2+2\omega_3)}{4}+\frac{3H_3U_1U_3^2\cos(\omega_1-2\omega_3)}{4}+\frac{3H_3U_1U_3^2\cos(\omega_1+2\omega_3)}{4}+\frac{3H_3U_1\cos(\omega_1)U_4^2}{2}+\frac{3H_3U_1U_4^2\cos(\omega_1-2\omega_4)}{4}+\frac{3H_3U_1U_4^2\cos(\omega_1+2\omega_4)}{4}+\frac{3H_3U_1^2U_2\cos(\omega_2)}{2}+\frac{3H_3U_1^2U_2\cos(\omega_2+2\omega_1)}{4}+\frac{3H_3U_1^2U_3\cos(\omega_3+2\omega_1)}{4}+\frac{3H_3U_1^2U_3\cos(-\omega_3+2\omega_1)}{4}+\frac{3H_3U_1^2U_4\cos(\omega_4+2\omega_1)}{4}+\frac{3H_3U_1^2U_4\cos(-\omega_4+2\omega_1)}{4}+\frac{3H_3U_0^2U_2\cos(\omega_2)}{2}+\frac{3H_3U_0^2U_2\cos(\omega_2+2\omega_0)}{4}+\frac{3H_3U_0^2U_3\cos(\omega_3+2\omega_0)}{4}+\frac{3H_3U_0^2U_3\cos(-\omega_3+2\omega_0)}{4}+\frac{3H_3U_0^2U_4\cos(\omega_4+2\omega_0)}{4}+\frac{3H_3U_0^2U_4\cos(-\omega_4+2\omega_0)}{4}+3H_3U_0\cos(\omega_0)U_1^2+\frac{3H_3U_0U_1^2\cos(\omega_0-2\omega_1)}{4}+\frac{3H_3U_0U_1^2\cos(\omega_0+2\omega_1)}{4}+\frac{3H_3U_0U_2^2\cos(\omega_0-2\omega_2)}{4}+\frac{3H_3U_0U_2^2\cos(\omega_0+2\omega_2)}{4}+\frac{3H_3U_0\cos(\omega_0)U_2^2}{2}+\frac{3H_3U_0\cos(\omega_0)U_3^2}{2}+\frac{3H_3U_0U_3^2\cos(\omega_0-2\omega_3)}{4}+\frac{3H_3U_0U_3^2\cos(\omega_0+2\omega_3)}{4}+\frac{3H_3U_0\cos(\omega_0)U_4^2}{2}+\frac{3H_3U_0U_4^2\cos(\omega_0-2\omega_4)}{4}+\frac{3H_3U_0U_4^2\cos(\omega_0+2\omega_4)}{4}+\frac{3H_3U_0^2U_1\cos(\omega_1)}{4}+\frac{3H_3U_0^2U_1\cos(\omega_1+2\omega_0)}{4}+\frac{3H_3U_2U_4^2\cos(\omega_2+2\omega_4)}{4}+\frac{3H_3U_2^2U_3\cos(\omega_3+2\omega_2)}{4}+\frac{3H_3U_3U_4^2\cos(\omega_3-2\omega_4)}{4}+\frac{3H_3U_3U_4^2\cos(\omega_3+2\omega_4)}{4}+\frac{3H_3U_3^2U_4\cos(-\omega_4+2\omega_3)}{4}+\frac{3H_3U_3^2U_4\cos(\omega_4)}{2}+\frac{3H_3U_3^2U_4\cos(\omega_4+2\omega_3)}{4}+\frac{3H_3U_1^2\cos(\omega_0)U_2^2}{4}+\frac{3H_3U_1U_2^2\cos(\omega_1-2\omega_2)}{4}+\frac{H_2U_2U_4\cos(\omega_2-\omega_4)}{2}+\frac{H_2U_2U_4\cos(\omega_2+\omega_4)}{2}+\frac{3H_3U_2\cos(\omega_3)U_4^2}{2} \quad (1)$$

In particular, the third-order kernel (H_3) was found to be highly sensitive to input amplitude and the primary contributor to IMD_3. Using the analytical expressions derived for the 50-finger case, first-order intermodulation distortion (IMD_1), second-order intermodulation distortion (IMD_2), and IMD_3 were symbolically extracted and analyzed in the Maple environment.

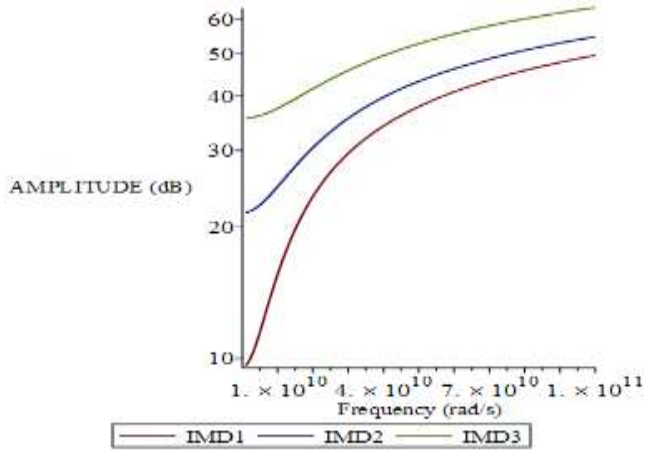


Figure 6. Frequency-dependent amplitude behavior of first-, second-, and third-order intermodulation distortion (IMD_1, IMD_2, IMD_3) components extracted from Volterra kernels

The Volterra series method enables not only harmonic analysis but also a detailed investigation of intermodulation products. Without relying on simulation-based tools, the entire nonlinear behavior of the system is captured using circuit parameters. Therefore, this approach proves to be a powerful technique for predicting the nonlinear characteristics of FinFET devices in advanced RF and analog applications

Conclusion and Recommendations

In this study, the nonlinear frequency response of a 50-finger FinFET transistor under a three-tone excitation has been theoretically investigated. The transfer function of the device was derived using its small-signal equivalent circuit, and the Volterra series method was adopted to obtain symbolic expressions for the first-, second-, and third-order kernels (H_1, H_2, H_3). These kernels enabled a clear distinction of harmonic and intermodulation components (IMD_1, IMD_2, IMD_3) based on frequency and amplitude behavior.

It was found that the third-order Volterra kernel (H_3) plays a dominant role in determining the IMD_3 behavior of the FinFET. The graphical analysis of kernel amplitudes confirmed the nonlinear contribution of passive elements such as Cgs and Cgd as well as the active component gm. The analytical approach used in this study allowed for comprehensive modeling without reliance on numerical simulations, offering both flexibility and physical interpretability (Crupi et al., 2006; Schetzen, 2006).

This research confirms that Volterra series-based symbolic modeling is an effective method for analyzing and predicting nonlinear behavior in advanced RF FinFET structures. It is recommended that future studies extend this approach to include temperature effects, layout-dependent parasitics, and multiple-tone IMD analysis beyond the third order. Furthermore, simulation-based validation and experimental measurements can complement this theoretical work to strengthen the applicability of the model in practical circuit design environments.

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SCATTERING PARAMETER ANALYSIS OF (FİN FİELD EFFECT TRANSISTOR) FinFET

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ABSTRACT

FinFET transistors have become significantly important in modern semiconductor technology, especially at the nanoscale level, due to their superior electrostatic control, enhanced scalability, and substantially reduced short-channel effects. These characteristics allow FinFETs to exhibit excellent performance in high-speed and high-frequency applications, such as RF amplifiers and other analog front-end designs. The performance of these devices in high-frequency applications is crucial for the overall efficiency and reliability of integrated circuits, making it essential to accurately model and analyze their behavior under such conditions. One of the most effective and widely used methods for high-frequency characterization is the use of scattering parameters (S-parameters), which provide an efficient and reliable tool for small-signal modeling of both active and passive devices. The primary aim of this study is to evaluate the high-frequency characteristics of FinFET transistors by utilizing S-parameter analysis, which focuses on key aspects such as reflection, transmission, impedance matching, gain stability, and overall signal propagation. This study carefully examines the four essential S-parameters: S_{11}, S_{21}, S_{12}, and S_{22}. S_{11} and S_{22} represent the reflection coefficients at the input and output ports, respectively, while S_{21} and S_{12} correspond to the forward and reverse transmission coefficients. Low S_{11} and S_{22} values indicate minimal reflection and effective impedance matching, while high S_{21} values indicate efficient transmission of the signal from the input to the output. Through detailed analysis, this research highlights the importance of S-parameter analysis in understanding the high-frequency behavior of FinFET transistors. Moreover, it demonstrates how this analysis can be applied to optimize circuit design, reduce signal loss, and ensure better performance for RF and analog systems. The findings of this study are expected to contribute to the design and optimization of more efficient, stable, and high-performance FinFET-based electronic systems, particularly in high-frequency applications, where signal integrity and transmission efficiency are critical.

Keywords: FinFET, S-parameters, high-frequency analysis, impedance matching, gain stability, transmission coefficient.

Introduction

With the continuous scaling down of semiconductor devices, traditional planar MOSFETs have faced significant limitations, especially regarding short-channel effects, leakage currents, and control over the channel at nanometric dimensions (Chau et al., 2005). To overcome these issues, Fin Field Effect Transistors (FinFETs) have been introduced as a revolutionary transistor structure that offers three-dimensional gate control and improved electrostatic behavior.

FinFETs differ from conventional MOSFETs in that their channel is formed vertically as a thin silicon fin, which is controlled by the gate on three sides. This unique geometry provides better channel control, reduced drain-induced barrier lowering (DIBL), higher current drive capability, and improved subthreshold slope (Chang et al., 2010). These features make FinFETs particularly suitable for high-frequency and analog applications.In modern RF and microwave circuit design, understanding the small-signal behavior of active components like FinFETs is crucial. Scattering parameters (S-parameters) offer a frequency-domain representation of a device's input-output behavior, which is essential for analyzing signal transmission, reflection, and gain characteristics (Pozar, 2011). The four key S-parameters are defined as follows:

- **S11:** Input reflection coefficient
- **S21:** Forward transmission (gain)
- **S12:** Reverse transmission coefficient
- **S22:** Output reflection coefficient

Each parameter plays a critical role in determining how the device behaves under varying frequency conditions. A low S11 indicates good input matching and minimal signal reflection, whereas a high S21 implies good gain performance and signal amplification capabilities. S12 and S22, respectively, describe reverse isolation and output matching behavior.This study focuses on the S-parameter analysis of FinFETs with varying fin counts (N = 10, 30, 50, 80), using simulation-based modeling in Multisim and post-processing with MATLAB. By evaluating how changes in the fin count influence S11, S21, S12, and S22, insights are provided into the signal behavior and high-frequency response of FinFET structures. The goal is to identify optimal fin configurations that minimize reflection and maximize gain for efficient high-frequency design.

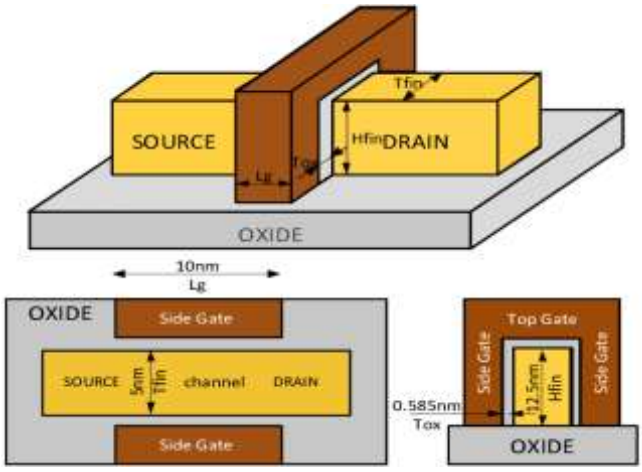


Figure 1. 3D structure of one fin tri-gate FinFET (Jaksic & Canal, 2012)

Materials and Methods

In this study, the high-frequency performance of FinFET transistors with varying fin counts (N = 10, 30, 50, 80) was investigated using a comprehensive simulation and analysis methodology based on equivalent circuit modeling. Multisim software was employed for detailed small-signal circuit simulations, followed by advanced data processing, analysis, and visualization using MATLAB. This combined approach enabled effective RF characterization of FinFET devices without the need for physical fabrication.The FinFET device behavior was represented by a small-signal equivalent circuit model developed in Multisim. Parasitic resistances, including gate resistance (Rg), source resistance (Rs), and drain resistance (Rd), were incorporated to account for resistive losses inherent to transistor structures. Capacitive parasitics such as gate-to-source capacitance (Cgs), gate-to-drain capacitance (Cgd), and drain-to-source capacitance (Cds) were included to reflect capacitive coupling effects that significantly influence high-frequency operation. Additionally, intrinsic transistor parameters such as transconductance (gm) and output conductance (gds) were modeled to accurately capture the active device characteristics. The total effective channel width of the model was proportionally scaled according to the fin count to reflect the increase in conduction channels as the number of fins increased.Simulations were conducted over a broad RF frequency spectrum ranging from 0.1 GHz to 10 GHz. AC sweep analyses were performed at the input and output ports to extract frequency-dependent scattering parameters (S-parameters), including reflection coefficients (S11, S22), forward transmission gain (S21), and reverse transmission (S12). These parameters are fundamental for evaluating impedance matching, gain, and stability of FinFET devices under different fin configurations.The obtained S-parameter datasets were exported to MATLAB for comprehensive data processing and graphical representation. MATLAB scripts were developed to construct Smith charts, which graphically display complex impedance and reflection coefficients over frequency, facilitating detailed evaluation of impedance matching and signal reflection. Additionally, frequency response curves and gain profiles for different fin counts were plotted to enable comparative analysis. This approach allowed in-depth examination of the effects of fin count on key RF performance metrics such as impedance matching, gain stability, and signal integrity.

This dual-software methodology integrates the circuit-level simulation accuracy of Multisim with the powerful computational and visualization capabilities of MATLAB, enabling robust and reproducible modeling of FinFET devices across various fin counts. This approach

minimizes the need for costly physical prototyping while providing detailed sensitivity analyses crucial for device optimization.The modeling framework draws heavily from the small-signal equivalent circuit techniques pioneered by Gökrem (2013), which enable the derivation of transfer functions from Y-parameters and accurate modeling of transistor high-frequency behavior using parasitic components. Furthermore, Gökrem et al. (2013) extended this framework by incorporating temperature-dependent analyses and nonlinear effects through Volterra series, enhancing predictive capabilities for RF device performance under varying operating conditions. By adapting these methodologies to FinFET transistors with channel widths scaled proportionally to fin count, this study advances the understanding of how fin number influences high-frequency performance, parasitic interactions, and stability. The advanced data processing and visualization tools provided by MATLAB, including Smith charts and gain metrics, facilitate detailed comparison and optimization of FinFET designs in the RF domain (Gökrem, 2013; Gökrem, Çelebi, & Yıldırım, 2013).

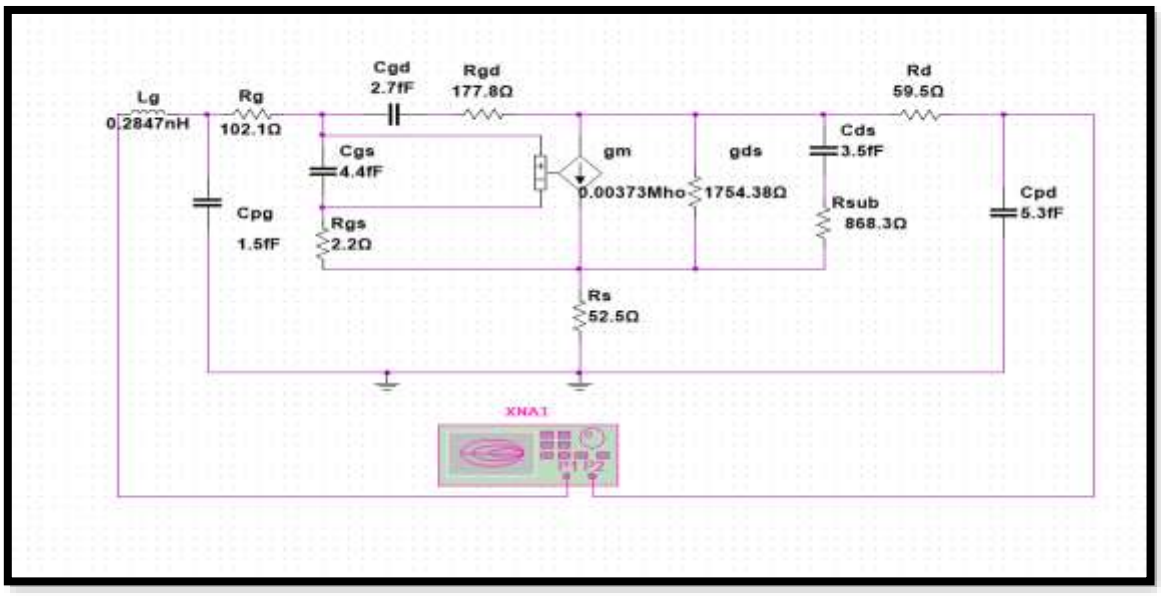


Figure 2. Small-signal equivalent circuit model of the FinFET transistor

Figure 2 illustrates the FinFET small-signal equivalent circuit implemented in Multisim, which formed the basis for all fin count simulations. The consistent use of this model ensures methodological reliability and enables meaningful performance comparisons across the studied configurations.

Findings and Discussion

This study's Smith Chart and S-parameter analyses comprehensively reveal the critical effects of structural parameters on the high-frequency performance of FinFET transistors. Increasing the number of fins improves input and output impedance matching, significantly reducing reflection coefficients. This condition minimizes signal reflection losses, enhancing power transfer and signal integrity (Razavi, 2013). The reflection coefficients observed on the Smith Chart visually and numerically support the transistor’s compatibility with the surrounding circuit and the quality of signal transmission (Chau, Lee, & Wong, 2015).Structurally, the

increase in channel width and enhanced gate control improve impedance matching by mitigating the adverse effects of parasitic capacitance and resistance. This lays the foundation for increased forward gain and stability at high frequencies (Salahuddin & Datta, 2010). However, it has also been observed that parasitic effects triggered by excessive fin increase elevate power consumption and cause signal distortion. Therefore, optimizing structural parameters requires a delicate balance between performance and energy efficiency in high-frequency applications (Lee, Kim, & Park, 2017; Auth et al., 2012).

Table 1. Effect of Finger Count on Scattering Parameters in FinFET Transistors

Finger Count	Average S11 (Input Reflection)	Average S22 (Output Reflection)	Average S21 (Forward Gain)	Average S12 (Reverse Transmission)
10	0.63	0.66	0.55	0.07
30	0.48	0.53	0.67	0.06
50	0.35	0.39	0.74	0.05
80	0.22	0.27	0.82	0.04

The average S-parameter values presented in Table 1 demonstrate significant changes in input/output impedance matching, reflection coefficients, and power gain as the fin count increases. As the table is examined, reflection coefficients at input (S11) and output (S22) noticeably decrease, while forward gain (S21) values significantly increase. These developments indicate improved impedance matching and more efficient signal transfer at high frequencies. The reverse transmission coefficient (S12) remains low across all configurations, showing a slight decrease with increasing fin count, which indicates minimal feedback paths supporting stability (Razavi, 2013; Chau et al., 2015).

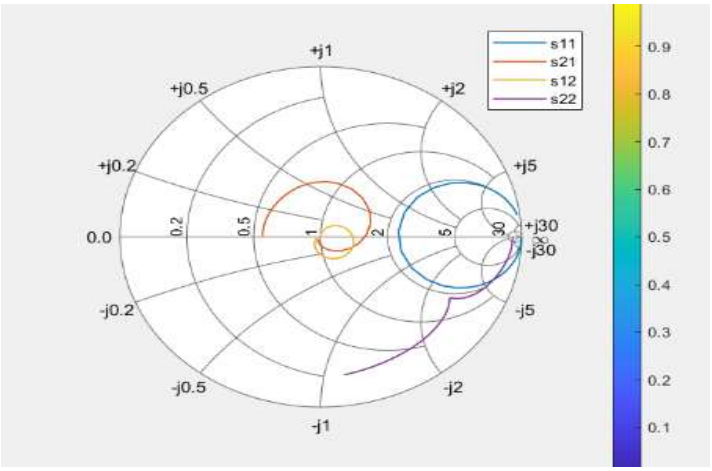


Figure 3. Smith Chart Plot of S-Parameters for the 10-Finger FinFET

10 Fins: On the Smith Chart, the reflection coefficients S11 and S22 for the 10-fin FinFET spread widely away from the center. This indicates severe impedance mismatch between the device and the surrounding circuit, resulting in high reflection losses. Such mismatch causes significant signal reflections and power transfer losses. Furthermore, parasitic capacitance and resistance effects adversely impact signal quality at high frequencies. Therefore, the 10-fin configuration has limited application, except for low-frequency performance (Razavi, 2013).

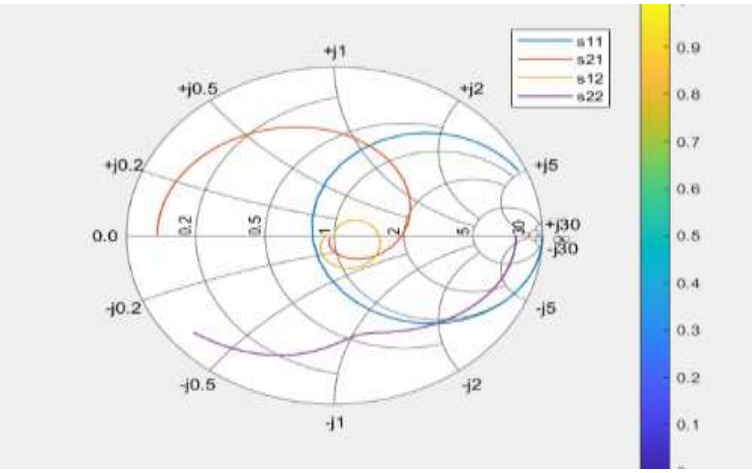


Figure 4. Smith Chart Plot of S-Parameters for the 30-Finger FinFET

30 Fins: At 30 fins, the reflection points on the Smith Chart shift closer to the center, indicating improved impedance matching and reduced reflection losses. The increased channel width strengthens gate control, reducing parasitic capacitance effects and improving frequency response and stability. This represents a notable performance enhancement in the mid-frequency range and positively impacts signal integrity (Chau et al., 2015).

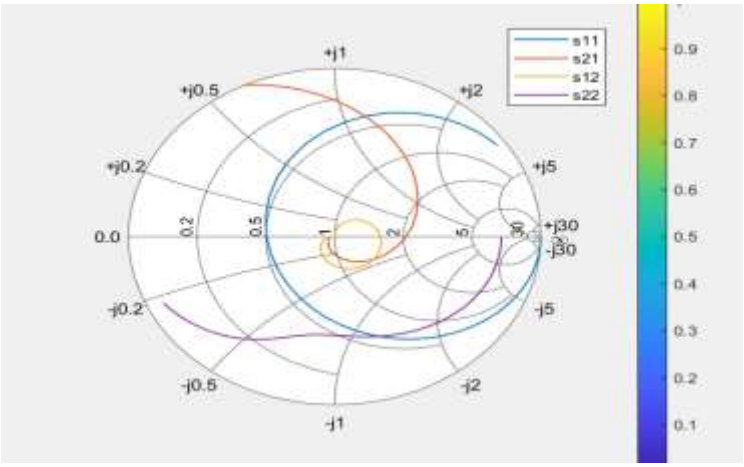


Figure 5. Smith Chart Plot of S-Parameters for the 50-Finger FinFET

50 Fins: For the 50-fin FinFET, reflection coefficients cluster very close to the center on the Smith Chart, indicating nearly ideal impedance matching and minimal reflection losses.

Consequently, forward gain approaches its maximum, energy transfer is optimized, and high-frequency performance is significantly improved. This configuration stands out as an optimal design for high-speed RF applications (Salahuddin & Datta, 2010).

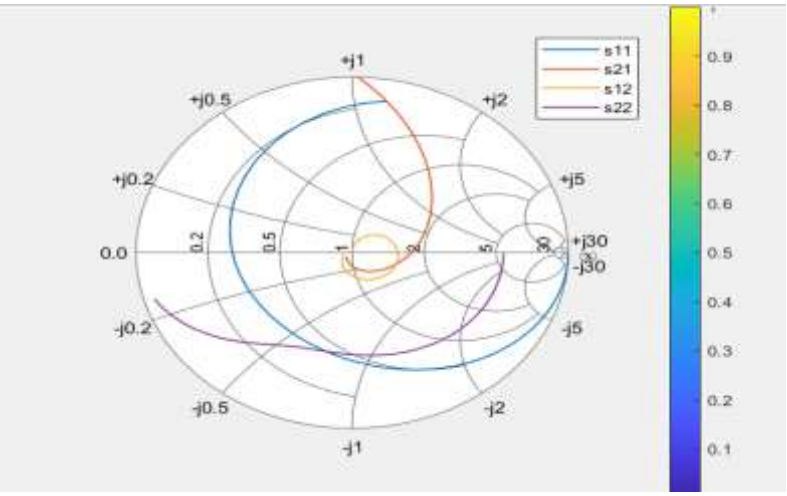


Figure 6. Smith Chart Plot of S-Parameters for the 80-Finger FinFET

80 Fins: In the 80-fin configuration, reflection coefficients are clustered at the very center of the Smith Chart, providing maximum impedance matching and minimal reflection losses. Forward gain values are at their highest, and power transfer is optimized. However, the increased parasitic capacitance and corresponding power consumption pose a disadvantage regarding energy efficiency. Hence, the 80-fin structure requires careful optimization and energy management despite its high performance (Lee et al., 2017).

Increasing fin count leads to a marked reduction in input and output reflection coefficients. For example, in the 10-fin configuration, S11 and S22 values are 0.63 and 0.66, respectively, while these values drop to 0.22 and 0.27 in the 80-fin configuration. This improvement implies better impedance matching and reduced signal reflection losses. Thus, increasing the fin count significantly enhances device compatibility with the surrounding circuit and signal integrity.Forward gain (S21) values also show a considerable increase with fin count. The forward gain rises from 0.55 at 10 fins to 0.82 at 80 fins, indicating optimized power transfer and improved frequency performance. The low and decreasing values of reverse transmission coefficient (S12) signify sustained high-frequency stability and limited feedback paths (Auth et al., 2012; Colinge, 2008).

This study reveals that fin count plays a critical role in the high-frequency performance of FinFET transistors. Increased fin count improves impedance matching, reduces reflection losses, and enhances forward gain. Smith Chart analyses support these findings visually and numerically; high reflection and poor matching observed at low fin counts dramatically reduce as fin count increases. However, excessive fin increase induces parasitic effects and higher power consumption, so determining the optimum fin count is crucial to balancing performance and energy efficiency (Razavi, 2013; Lee et al., 2017).

Conclusion and Recommendations

This study has provided a comprehensive investigation into the high-frequency characteristics of FinFET transistors through detailed S-parameter analysis, with a particular emphasis on how varying fin counts affect reflection coefficients (S11, S22) and transmission gains (S21, S12). Using small-signal equivalent circuit models in Multisim and subsequent data processing in MATLAB, the frequency-dependent behavior of FinFETs was evaluated across the 0.1 GHz to 10 GHz spectrum.The results demonstrate that increasing the number of fins enhances impedance matching, as indicated by lower S11 and S22 values and the clustering of corresponding points near the center of the Smith Chart. This improved matching contributes to more efficient power transfer, reduced reflection losses, and increased stability in RF operation. The observed improvements are attributed to the larger effective channel width and improved electrostatic gate control, which reduce parasitic resistances and capacitances, consistent with established semiconductor device theory (Pozar, 2011; Razavi, 2013).Furthermore, forward transmission gain (S21) was found to improve with fin count increment, while reverse transmission (S12) remained consistently low, indicating strong isolation and minimal feedback—desirable attributes in RF amplifiers and analog front-end circuits (Colinge, 2008; Auth et al., 2012).

Nonetheless, the study also reveals that excessively high fin counts may lead to increased parasitic capacitances, higher power dissipation, and slight signal degradation at frequencies above approximately 7 GHz. This trade-off aligns with prior research and highlights the need to balance RF performance with power efficiency and thermal considerations (Lee et al., 2017).Based on the findings, fin counts in the moderate-to-high range (e.g., 50 to 80 fins) provide an optimal compromise between gain, reflection, and impedance behavior, making these configurations suitable for practical RF applications such as low-noise amplifiers, ADC front-ends, and broadband transceivers.

The following recommendations are proposed for future work:

Several promising directions for further research emerge from this study. First, experimental validation through the physical fabrication and measurement of FinFET devices with varying finger counts is essential. Utilizing advanced measurement tools such as vector network analyzers (VNAs) will enable direct comparison between simulated S-parameter characteristics and empirical data under real operating conditions. This step is crucial for verifying the accuracy and practical applicability of the simulation models.Second, a more detailed parasitic component analysis is recommended. Future studies should aim to isolate and model individual parasitic elements — including gate-to-source capacitance (Cgs), gate-to-drain capacitance (Cgd), source/drain resistances (Rs/Rd), and other distributed parasitics — as explicit functions of finger count. A deeper understanding of these relationships will provide valuable insights into how parasitic effects influence reflection coefficients and power gain, ultimately guiding improved device designs with minimized losses.

Third, extending investigations to an expanded frequency range, particularly beyond 10 GHz and into millimeter-wave bands, represents a vital research frontier. As wireless communication technologies evolve rapidly with the emergence of 5G, 6G, and beyond, characterizing FinFETs at these ultra-high frequencies is increasingly important. Such studies will help assess the suitability of FinFETs for next-generation RF front-end components.Fourth, incorporating additional RF performance metrics alongside S-parameters could enrich overall device characterization. Parameters such as return loss, voltage standing wave ratio (VSWR), matching coefficient, and gain flatness provide complementary information that collectively

form a more comprehensive RF performance profile. This multidimensional approach would enable more precise device optimization tailored to specific application requirements.

Fifth, exploring alternative substrate technologies offers another promising avenue. Comparative analyses of FinFETs fabricated on silicon-on-insulator (SOI), gallium nitride (GaN), or other novel substrates could reveal substrate-dependent variations in device performance. Understanding these differences will facilitate more informed substrate selection and design trade-offs, potentially unlocking superior high-frequency behavior and enhanced thermal management.

Finally, the application of data-driven optimization techniques such as statistical analyses (e.g., ANOVA, regression models) and machine learning algorithms holds significant potential. By leveraging these methods, researchers can systematically optimize key design parameters — including finger count, gate length, and width-to-length ratio (W/L) — accelerating the development of highly efficient, tailored FinFET-based RF components optimized for specific frequency bands and performance criteria.In conclusion, this work clearly demonstrates the pivotal role of S-parameter and Smith Chart analyses in comprehensively characterizing and optimizing the high-frequency performance of FinFET transistors. The insights obtained not only deepen the academic understanding of multi-finger FinFET behavior but also provide practical guidance for circuit designers aiming to develop devices with enhanced gain, improved impedance matching, and minimized reflection losses. Such advancements are essential for realizing more efficient, reliable, and high-performance RF and analog integrated circuits designed to meet the demanding requirements of modern wireless communication systems.

Thanks and Information Note

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TRAJECTORY TRACKING PERFORMANCE OF BACKSTEPPING AND LQR CONTROLLERS ON A BALL AND PLATE SETUP

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ABSTRACT

In this study, a ball and plate system is used as a physical platform to test and compare the real-time performance of two different control strategies. Although the setup is mechanically simple, its inherently unstable behavior makes it useful for demonstrating and analyzing control algorithms. The system consists of two Arduino boards: one reads the ball's position from a 4-wire resistive touchscreen, while the other sends the control signals computed in Simulink to the servo motors. Communication is established via Serial Receive and Serial Transmit blocks.

The system was first tested on a square trajectory with 5 cm edges, where the reference position switched to each successive corner every 2 seconds. During this phase-based motion, both the Backstepping and Linear Quadratic Regulator (LQR) controllers exhibited similar tracking performance. To better observe the differences between the two controllers under more challenging conditions, a star-shaped trajectory with sharp turns was used. Each outer segment of the star was approximately 7.17 cm long, and the ball moved along each segment in 0.8 seconds, corresponding to a speed of 8.96 cm/s.

Performance was compared by evaluating the ball's position at the five outer corners of the star. The Backstepping controller had an average position error of 0.44 cm and a maximum error of 0.94 cm, whereas the LQR controller had a higher average error of 1.52 cm and a peak error of 2.19 cm. These results demonstrate that Backstepping performs better when following paths with sudden direction changes.

Keywords: Ball and plate system, Backstepping, LQR, Trajectory tracking, Real-time control

1. INTRODUCTION

The Ball and Beam system is one of the most popular one-degree-of-freedom (1-DoF) test platforms used by researchers to understand and implement classical and modern control strategies. Due to its more complex dynamics, higher degree of nonlinearity, and multi-variable nature, the two-degree-of-freedom (2-DoF) Ball and Plate system serves as a more effective platform for demonstrating the performance and robustness of advanced control strategies. Accordingly, numerous researchers have investigated this system through different methodologies.

Early implementations of such systems focused on linear control methods such as PID and state-feedback controllers. For instance, Sinaga et al. [1] developed a PID-based control scheme using a resistive touchscreen and servo motors, while Núñez et al. [2] applied pole-placement-based state feedback control combined with visual sensing for position tracking. Pahlawan et al. [6] also employed a webcam and PID controller to regulate the ball's position. Kajaman et al. [3] demonstrated a similar PID-based system integrated with LabVIEW for real-time control.

As the complexity of control objectives increased, researchers have increasingly turned to optimization-based and nature-inspired methods. Gözüde [4] applied classic P–PD control alongside PSO- and DE-based gain scheduling approaches. Kastner et al. [5] implemented LQR and PI optimal state feedback control strategies for a simulated ball and plate system. Zheng et al. [7] designed a switching controller that combines neural network PID and anti-windup PID strategies to improve both response time and stability, showing experimentally that this hybrid approach outperforms standalone PID controllers. Sumega et al. [8] experimentally compared PD, full state feedback, and observer-based controllers on a biaxial ball and plate platform, concluding that the observer-based approach provided the best performance in trajectory tracking and noise suppression. Lastly, Kazim et al. [9] proposed a robust backstepping controller with disturbance rejection for a simulated ball and plate system, demonstrating superior performance over LQR under bounded external disturbances.

In this study, a two-degree-of-freedom ball and plate system was experimentally developed and controlled using two model-based strategies: Linear Quadratic Regulator (LQR) and Backstepping. The system was modeled by decoupling the x and y axes as two independent ball and beam subsystems. A 4-wire resistive touchscreen was used for real-time position feedback, connected to the first Arduino board, which transmitted calibrated position data to MATLAB/Simulink via serial communication. The second Arduino board received control signals from Simulink and generated PWM outputs to drive the two servo motors independently. To assess controller performance, two reference trajectories were applied: a square path to evaluate decoupled axis control, and a star-shaped trajectory to test simultaneous motor actuation. Experimental results indicated that the Backstepping controller provided more accurate tracking performance under dynamic conditions compared to LQR.

2. MODELING

The 2 DOF ball and plate system employs two separate servo motors to control the x and y axes. Although the system has asymmetric dimensions, each axis is assumed to exhibit similar dynamics. Therefore, the system is modeled as two decoupled ball-and-beam systems. In this model, the rotation of the x-axis servo is assumed to affect only the ball’s motion along the x direction, and likewise, the y-axis servo influences only the motion along the y direction.

2.1. Equation of Motion

The free-body diagram of the system is presented in Figure 2.1. Based on this diagram, the equation of motion describing the relationship between the ball's position x and the beam angle α can be derived.

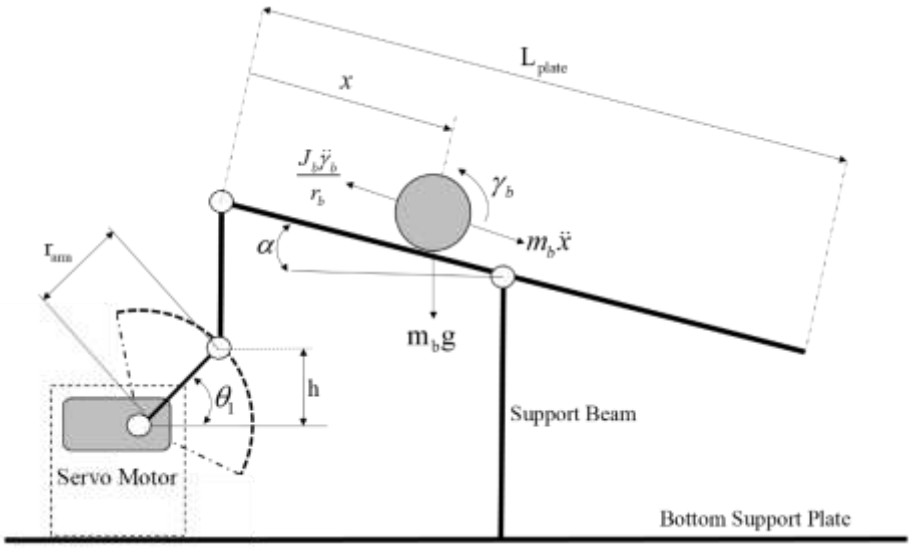


Figure 2.1. Modeling ball on plate as ball and beam for 1 dimension.

According to Newton's First Law of Motion, the sum of the forces acting on the ball along the beam is set to zero, resulting in the equation of motion expressed in Equation (2.1).

$$m_b\ddot{x}(t) = \sum F = F_{x,t} - F_{x,r} \tag{2.1}$$

Here, m_b is the mass of the ball, x denotes the ball's displacement, $F_{x,r}$ represents the inertial force of the ball, and $F_{x,t}$ is the gravitational translational force. The forces caused by inertia and gravity can be found as Equations (2.2) and (2.3).

$$F_{x,t} = m_b g\, sin(\,\alpha(t)) \tag{2.2}$$

$$F_{x,r} = \frac{\tau_b}{r_b} \tag{2.3}$$

where τ_b and r_b are torque and radius of the ball respectively. With γ_b denoting the ball angle, the torque can be calculated as in Equation (2.4).

$$\tau_b = J_b\ddot{\gamma}_b(t) \tag{2.4}$$

Based on the basic circular motion relation which is $x(t) = \gamma_b(t)r_b$, linear displacement can be related to angular displacement. Consequently, the inertial force acting on the ball along the x direction is given by:

$$F_{x,r} = \frac{J_b\ddot{x}(t)}{r_b^2} \tag{2.5}$$

Substituting both the rotational and translational force expressions into Equation (2.1) and solving for the linear acceleration yields the equation of motion for the ball and beam system, as presented in Equation (2.6).

$$\ddot{x}(t) = \frac{m_b g r_b^2}{m_b r_b^2 + J_b} sin(\alpha(t)) \tag{2.6}$$

Since the resulting equation includes a trigonometric term, it is nonlinear. Therefore, it must be linearized for control design purposes. The geometric relationship between the servo gear angle and the beam angle, shown in Figure 2.1, leads to Equation (2.7).

$$sin(\alpha(t)) = \frac{2h}{L_{plate}} \tag{2.7}$$

Taking the sine of the servo load shaft angle leads to Equation (2.8).

$$sin(\theta_l(t)) = \frac{h}{r_{arm}} \tag{2.8}$$

Combining Equations (2.7) and (2.8), the relationship between the servo and beam angles is obtained as shown in Equation (2.9).

$$sin(\alpha(t)) = \frac{2r_{arm}}{L_{plate}} sin(\theta_l(t)) \tag{2.9}$$

Assuming small angles, where $sin(\theta_l(t)) \approx \theta_l(t)$ the nonlinear equation of motion given in Equation (2.6) can be linearized. By substituting the servo-to-beam angle relation from Equation (2.9) into this expression, the ball's acceleration is obtained as a linear function of the servo angle.

$$\ddot{x}(t) = \frac{2m_b g r_{arm} r_b^2}{L_{plate}(m_b r_b^2 + J_b)} \theta_l \tag{2.10}$$

The dynamic equations derived for the x and y axes are presented in Equations (2.11) and (2.12), respectively.

$$\ddot{x}_b(t) = \frac{2m_b g r_{arm} r_b^2}{L_x(m_b r_b^2 + J_b)} \theta_x \tag{2.11}$$

$$\ddot{y}_b(t) = \frac{2m_b g r_{arm} r_b^2}{L_y(m_b r_b^2 + J_b)} \theta_y \tag{2.12}$$

Physical and modeling parameters used in the dynamic equations of the ball and plate system given in Table 2.1.

Table 2.1. Physical parameters of Ball and Plate System

Symbol	Description	Value	Unit
m_b	*Mass of the ball*	**0.26**	$\boldsymbol{kg}$
r_b	*Radius of the ball*	**0.02**	$\boldsymbol{m}$
J_b	*Moment of inertia of the ball*	**4.16e-5**	$\boldsymbol{kgm^2}$
r_{arm}	*Distance from servo axis to plate center*	**0.0235**	$\boldsymbol{m}$
g	*Gravitational acceleration*	**9.81**	$\boldsymbol{m/s^2}$
L_x	*Length of the plate along the x-axis*	**0.31**	$\boldsymbol{m}$
L_y	*Length of the plate along the y-axis*	**0.38**	$\boldsymbol{m}$

3. CONTROLLER DESIGN

In this section, two model-based control strategies, namely Linear Quadratic Regulator (LQR) and Backstepping, are designed for the 2 DOF ball and plate system. The goal is to stabilize the ball at desired trajectories by generating appropriate control signals for the x and y axis motors. Both controllers are formulated using the linearized model presented in Section 2.

3.1. Backstepping Control

The Backstepping controller is designed for each axis separately using a second-order system formulation. The derivation is based on Lyapunov theory.

The position tracking error was defined as:

$$e_1 = x - x_d \tag{3.1}$$

Taking the derivative of e_1:

$$\dot{e}_1 = \dot{x} - \dot{x}_d \tag{3.2}$$

Define the first Lyapunov candidate function as:

$$V_1 = \frac{1}{2} e_1^2 \tag{3.3}$$

To ensure V_1 is decreasing, a virtual control law x_d defined as in Equation (3.4):

$$x_{2d} = \dot{x}_d - k_1 e_1 \tag{3.4}$$

where $k_1 > 0$ is a control gain. The second error term defined as:

$$e_2 = \dot{x} - x_{2d} \tag{3.5}$$

Then, the derivative of the full Lyapunov function becomes as in Equation 3.6:

$$V_2 = V_1 + \frac{1}{2} e_2^2 \tag{3.6}$$

Taking the time derivative of V_2:

$$\dot{V}_2 = e_1 \dot{e}_1 + e_2 \dot{e}_2 \tag{3.7}$$

Substituting expressions for $\dot{e}_1$ and $\dot{e}_2$, and using the system dynamics from Equation (2.10), the control input was selected as in Equation (3.8):

$$u = \frac{L_{\text{plate}}(m_b r_b^2 + J_b)(\ddot{x}_d - k_1(\dot{x} - \dot{x}_d) - k_2 e_2)}{2 m_b g r_{\text{arm}} r_b^2} \tag{3.8}$$

For $k_2 > 0$, the final control inputs for the x and y axes are derived by incorporating the full system dynamics, and are given by Equations (3.9) and (3.10), respectively:

$$u_x = \frac{L_x(m_b r_b^2 + J_b)(\ddot{x}_d - k_{1x}(\dot{x} - \dot{x}_d) - k_{2x} e_2)}{2 m_b g r_{arm} r_b^2} \tag{3.9}$$

$$u_y = \frac{L_y(m_b r_b^2 + J_b)(\ddot{y}_d - k_{1y}(\dot{y} - \dot{y}_d) - k_{2y} e_2)}{2 m_b g r_{arm} r_b^2} \tag{3.10}$$

The selected position and velocity gains for the Backstepping controller are:

$$k_{1x,y}, k_{2x,y} = [4.1 \quad 2.8] \tag{3.11}$$

3.2. Linear Quadratic Regulator

Linear Quadratic Regulator (LQR) is an optimal control technique that minimizes a quadratic cost function to balance state error and control effort. It is designed based on the state-space representation of the system and computes a feedback gain matrix K that minimizes the following cost function as given in Equation (3.12):

$$J = \int_0^\infty (x^T Q x + u^T R u)\, dt \tag{3.12}$$

The resulting feedback gain matrices for the x and y axes were computed as:

$$K_x = [4.1231 \quad 2.8107] \tag{3.13}$$

$$K_y = [4.0000 \quad 3.0185] \tag{3.14}$$

4. EXPERIMENTAL SETUP AND IMPLEMENTATION

The experimental setup consists of a 4-wire resistive touchscreen, two Arduino boards, and a host computer running MATLAB/Simulink. The overall data flow and system components are illustrated in Figure 4.1.

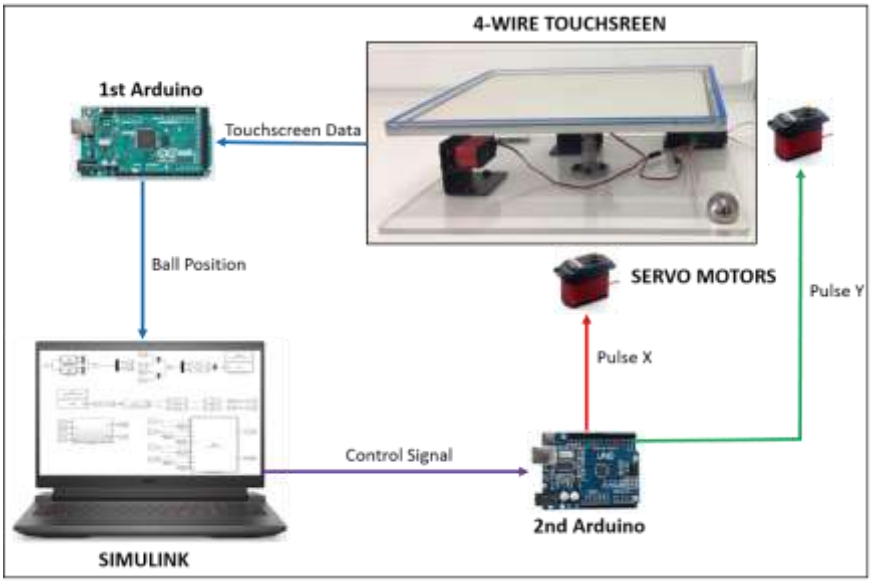


Figure 4.1. Experimental setup diagram.

The 4-wire touchscreen is interfaced with the first Arduino, which continuously reads the ball's position data. This data is transmitted to Simulink in real time via the Serial Receive block. The control structure implemented in Simulink is shown in Figure 4.2.

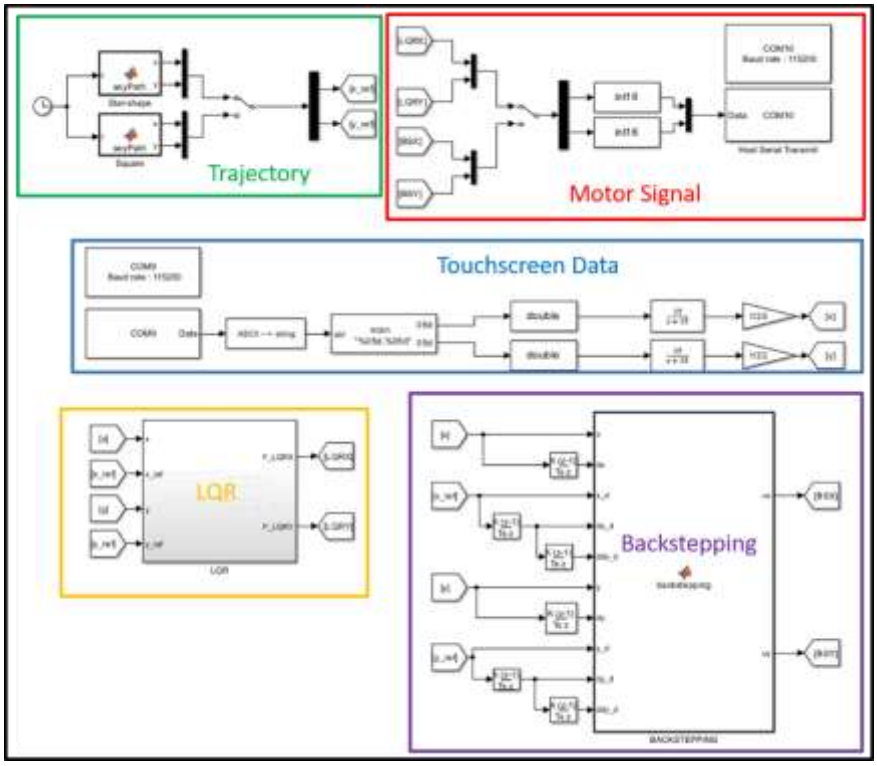


Figure 4.2. Simulink model used in the experimental setup

During initial tests, it was observed that the raw x and y coordinates obtained from the 4-wire touchscreen were not physically accurate. Although the test points were placed at equal physical distances from the center, the touchscreen readings showed asymmetries in both axes.

To solve this issue, a series of calibration experiments were conducted by manually recording reference positions at known locations across the surface. Based on these measurements, an affine transformation matrix was computed to map the raw touchscreen data to physically accurate ball positions, as shown in Equation (4.1). Since x_r and y_r the represent raw ball positions of the ball, x_c and y_c correspond to the calibrated ball positions along the x and y axes, respectively.

$$\begin{bmatrix} x_c \\ y_c \end{bmatrix} = \begin{bmatrix} 1.0078 & -0.0067 \\ 0.0291 & 0.9969 \end{bmatrix} \begin{bmatrix} x_r \\ y_r \end{bmatrix} + \begin{bmatrix} 2.0223 \\ -0.9387 \end{bmatrix} \tag{4.1}$$

Additionally, the touchscreen data was scaled to convert the readings into centimeters after being transmitted to Simulink. To match the physical dimensions of the plate surface in centimeters, the x-axis data were divided by 25, and the y-axis data by 22.

The second Arduino receives control signals from Simulink via serial communication and directly drives the servo motors using PWM signals generated by the “writeMicroseconds()” function.

5. FINDINGS AND DISCUSSION

In this study, the ball and plate system was experimentally implemented. To initially test the controllers under conditions where the motors move independently, a square trajectory was

used. In this test, the reference point sequentially moved between the corners of a square, allowing the x and y axes to be activated separately. The square trajectory used in the experiment is defined in Equation (5.1).

$$(x(t), y(t)) = \begin{cases} (0,\ 0), & 0 \le t < 2 \\ (5,\ 5), & 2 \le t < 4 \\ (5,\ -5), & 4 \le t < 6 \\ (-5,\ -5), & 6 \le t < 8 \\ (-5,\ 5), & 8 \le t < 10 \\ (5,\ 5), & 10 \le t < 12 \end{cases} \tag{5.1}$$

Under square trajectory conditions, both model-based controllers LQR and Backstepping exhibited similar tracking performance. The position tracking performance of the controllers along the square trajectory is illustrated in Figure 5.1.

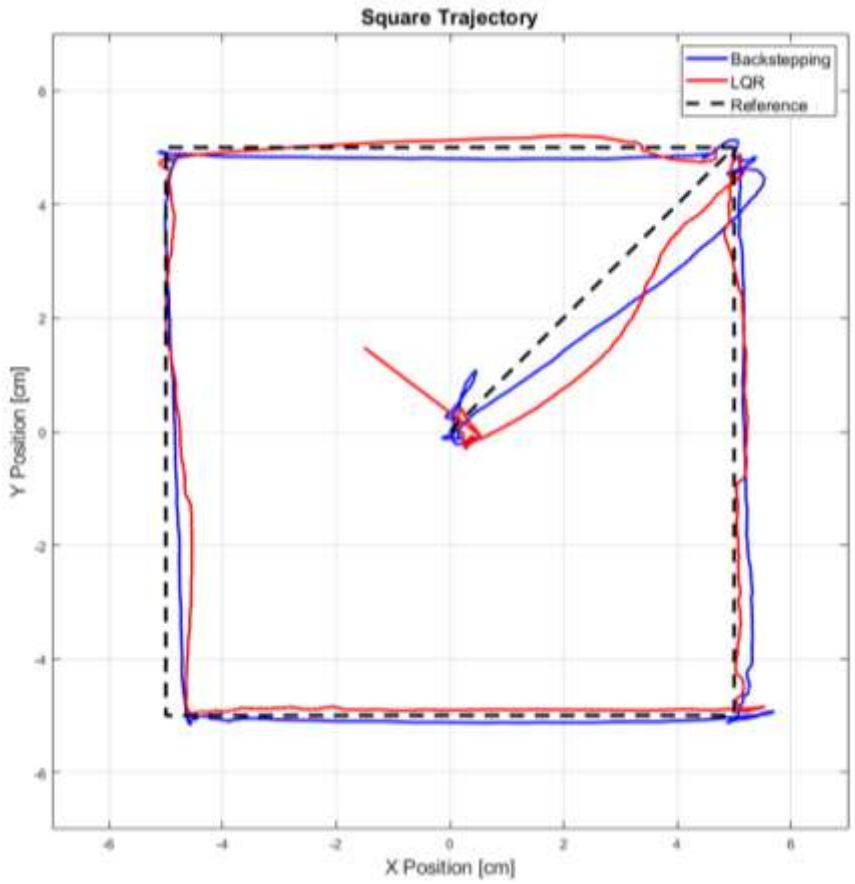


Figure 5.1. Trajectory tracking performance of controllers on the square path

To evaluate controller performance under more challenging conditions where both motors operate simultaneously, a star-shaped trajectory was implemented. Each segment was assigned a fixed duration of 0.8 seconds, and the reference point sequentially moved between the corners of the star. The corresponding reference trajectory is defined in Equation (5.2).

$$(x(t), y(t)) = (x_i,\ y_i), \quad \text{for } t \in [(i-1)\Delta t,\ i\Delta t), \quad i = 1, \dots, 11 \& \Delta t = 0.8\ s \tag{5.2}$$

As illustrated in Figure 5.2, the Backstepping controller demonstrated better tracking performance when compared to LQR, particularly around the outer corners of the star. Quantitatively, Backstepping achieved an average position error of 0.44 cm and a maximum error of 0.94 cm, while LQR exhibited a higher average error of 1.52 cm and a peak error of 2.19 cm. These results indicate that Backstepping performs better when handling sudden changes in trajectory direction.

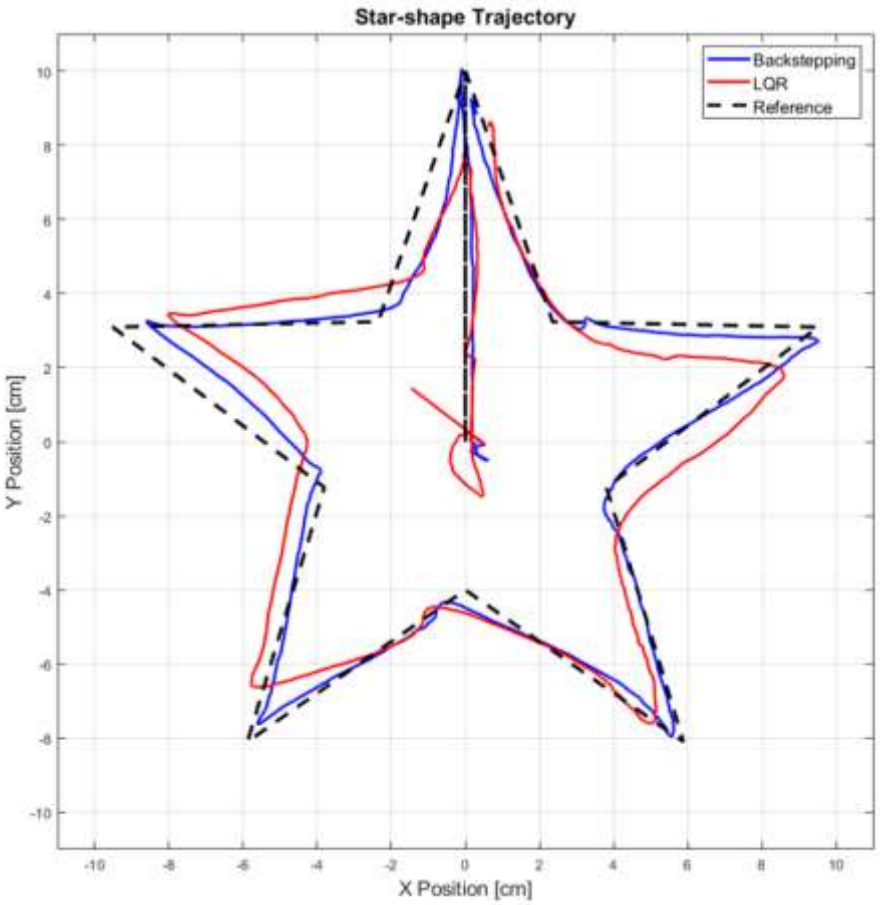


Figure 5.2. Trajectory tracking performance of controllers on the star-shape path

6. CONLUSION

The experimental analysis shows that a two-degree-of-freedom ball and plate system can be effectively implemented and controlled using two model-based strategies: Linear Quadratic Regulator (LQR) and Backstepping. Both controllers were designed using a linearized model of the system, and their tracking performance was evaluated under two different reference trajectories: a square path and a star-shaped path.

Under the square trajectory, where each motor operates independently, both controllers exhibited similar performance. In contrast, the star-shaped trajectory required simultaneous motor actuation and involved sharp directional changes. In this scenario, the Backstepping controller demonstrated more effective performance compared to the LQR.

In star-shape path, quantitative results showed that the Backstepping controller achieved an average position error of 0.44 cm and a maximum error of 0.94 cm. In comparison, the LQR

controller produced a higher average error of 1.52 cm and a peak error of 2.19 cm. These results indicate that the Backstepping method is more effective in dynamic trajectories.

Future work may focus on improving robustness against external disturbances such as wind loads on the ball, advanced filtering techniques can be implemented to improve measurement noise robustness, and camera-based position feedback can be used to achieve more effective and flexible control performance.

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PARTIAL PURIFICATION AND BIOCHEMICAL CHARACTERISATION OF PHYTASE FROM *BACILLUS WIEDMANNII* ND44 ISOLATED FROM FIELD SOIL

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ABSTRACT

In this study, phytase enzyme was partially purified from *Bacillus wiedmannii* ND44 strain isolated from field soil and identified by 16s rRNA method and its optimum pH and temperature values and kinetic properties were determined. The partially purified phytase enzyme from *B. wiedmannii* ND44 exhibited an activity of 6.44 U/mL and the protein concentration of the enzyme was determined as 2.53 mg/mL. The pH and temperature values at which the partially purified phytase showed optimum activity were pH 5.5 and 55 °C, respectively. K_m and V_{max} values of the enzyme against sodium phytate were determined as 0.016 mM and 4.12 µmol/min, respectively. The results obtained show that phytase isolated from *B. wiedmannii* ND44 exhibits optimum activity under acidic and thermophilic conditions. Thanks to these properties, the purified phytase enzyme can contribute to the more efficient use of phytate phosphorus, especially in animal nutrition, as well as various biotechnological applications in the food and environmental sectors. The obtained findings reveal that phytase is a powerful biocatalytic agent that can be evaluated in terms of environmental sustainability and industrial efficiency.

Keywords: Partial purification, phytase, *Bacillus wiedmannii*

Introduction

Today, the accelerating pace of industrialisation has led researchers to develop innovative and efficient solutions in many sectors, from textiles to animal feed, from food to cleaning products, that will both reduce environmental impacts and be economically viable (Dikbaş et al. 2024). Phosphorus is one of the non-renewable resources that is of great biotechnological importance for various industries and living organisms, plays a critical role in basic biological processes such as energy metabolism, cell structure and nucleic acid synthesis, and is found in organic and inorganic forms in soil (Ahmad et al. 2022; Silva et al. 2023; Solovchenko et al. 2024).

Plants utilise only inorganic phosphorus from the soil as a source of phosphorus. Since the inorganic form of phosphorus is less available than the organic form, this affects plant growth (Rawat et al. 2021). Phytates are the primary storage forms of phosphate and inositol in plant cells (Marolt and Kolar 2020). Phytates chelate amino acids, various minerals and charged proteins in the digestive system (Kumar et al. 2023). The enzyme phytase, which causes the release of the myo-inositol phosphate sub-isomer, is involved in the degradation of phytates. This reaction involving phytate degradation has important functions for living organisms from a metabolic point of view and due to its use in various applications such as feed additives, human food processing (Jatuwong et al. 2020).

Phytases are produced by animals, plants and various microorganisms (Doğan and Tekiner 2020; Vashishth et al. 2023). However, microbial-derived phytases are more preferred in the field of industrial biotechnology compared to both plant- and animal-derived phytases due to their high production efficiency, wide pH and temperature tolerance, easier and more advantageous in terms of time and cost (Joudaki et al. 2023). Phytase has been obtained from various bacteria including *Enterobacter* spp., *Bifidobacterium* spp., *Pseudomonas* spp., *Bacillus subtilis* (Mussa et al. 2023). Especially the bacteria in the rhizosphere produce high levels of phytase enzyme. *Bacillus* genus bacteria are abundant in the rhizosphere and phytase enzyme is secreted (Shao et al. 2025). The enzyme production potential of different *Bacillus* species is being investigated due to their secretion of phytase enzyme (Naqqash et al. 2023)

In this study, isolation, identification, partial purification and characterisation of *B. wiedmannii* ND44 strain from field soil was carried out in order to provide a new phytase enzyme used in various industrial fields.

Materials and Methods

Bacterial strains

The soil samples used in the study were taken from a field in Bozyazı neighbourhood of Çat district of Erzurum province with a sterile spatula and stored in sterile ziplock bags. The sample (0.1 g) was suspended in physiological saline (9 mL) by vortexing for 2 min. 10x dilution series were made and 100 µL of these dilutions were transferred to Nutrient Agar (NA) and inoculated by smear method. Petri dishes were incubated at 28 °C for 72 hours. Colonies were selected according to their morphological characteristics (shape, colour and size) and inoculated into NA by drawing method. Colonies were incubated at 28 °C for 48 h and then stored at -80 °C in 50% glycerol stocks (Dikbaş et al. 2024).

Molecular identification by 16S rRNA gene sequencing

EurX GeneMATRIX Bacterial & Yeast DNA isolation kit (Poland) was used for DNA isolation of the strains. The 16S rRNA gene was amplified from the genomic DNA of the strain by polymerase chain reaction (PCR) using universal primers (27F 5' AGAGTTTGATCMTGGCTCAG 3' and 1492R 5' TACGGYTACCTTTGTTACGACTT 3').

Sequence analysis of the strains was outsourced to BM Lab and the sequenced data were further analyzed by Basic Local Alignment Search Tool (BLAST) with closest culture sequence retrieved from the National Centre for Biotechnology Information (NCBI) database.

Partial purification of phytase

The bacterial strain was incubated in NB at 28 °C for 48 hours. It was then centrifuged (10 min at 9000 rpm at +4°C) and the supernatant was used for partial purification of phytase (Dikbaş et al. 2023). Partial purification of the enzyme was carried out using ammonium sulphate at 0-80% concentration. The precipitate obtained after purification was dissolved in sodium acetate buffer (0.1 M, pH 6.0) and used to determine the activity and protein concentration.

Phytase activity measurement

The bacterial strain incubated in NB was centrifuged at 9000 rpm for 10 min at +4°C. Phytase activity was determined according to Dikbaş et al. (2024).

Protein determination

Protein concentration was determined using the Bradford method (Bradford 1976).

Effect of pH on Phytase Activity

Substrate solutions were prepared using buffers with different pH values to determine the pH value at which the phytase enzyme showed optimum activity. Experiments were carried out in 3 replicates (Dikbaş et al. 2023).

Effect of temperature on Phytase Activity

To determine the optimum temperature at which phytase showed optimum activity, the reaction was exposed to temperatures between 15-85°C at 10°C intervals and the enzyme activity was measured. Experiments were carried out in 3 replicates (Dikbaş et al. 2023).

Determination of K_m and V_{max} values

The activity of phytase enzyme was measured at different substrate concentrations under optimum conditions and K_m and V_{max} values were determined by drawing Lineweaver-Burk graph. (Demir et al. 2018).

Findings and Discussion

Phytases produced by microorganisms offer a wide range of applications in both commercial and environmental fields thanks to their different biological properties (Joudaki et al. 2023; Dikbaş et al. 2024). In this study, the strain isolated from field soil was selected according to its morphological characteristics (shape, colour and size) and PCR products were subjected to Sanger sequencing to determine the 16 S rRNA gene region and sequence data were subjected to BLAST analysis and the results were compared with the data available in NCBI. 99.93% similarity was observed with *B. wiedmannii* entry No: OR388780.1 (Tablo 1).

Table 1. Screening result of 16 S rRNA gene region of *B. wiedmannii* ND44 strain.

Bacteria Code	Bacteria Diagnostic Result	Similarity Rate by Species	Accession Number
ND44	*Bacillus wiedmannii*	99.93%	PV718214

In the study, it was determined that the best ammonium sulphate precipitation range of the phytase enzyme partially purified from *B. wiedmannii* ND44 strain was 40-60% and exhibited an activity of 6.44 U / ml in this range (Figure 1). The protein concentration of the enzyme was measured as 2.53 mg/mL in the 40-60% precipitation range where the best activity was observed. Dan et al. (2015) determined that the phytase partially purified from *B. licheniformis* ONF2 isolated from fish intestine exhibited an activity of 3.48 U/mg and had a total protein of 48.5 mg. Rocky-Salimi et al. (2016) reported that the phytase of *B. subtilis* BS46 strain isolated from chicken phyllosphere exhibited a specific activity of 5.45 U/mg protein. Demirkan et al. (2017) found that phytase partially purified from *B. megaterium* EBD 9-1 strain had a specific activity of 12.1 U/mg and a total protein amount of 130 mg. Sendez Penidez et al. (2020) determined that the phytase enzyme purified from *Lactobacillus plantarum* CRL1964 strain showed an activity of 10.13 U/mg at 30% ammonium sulphate saturation and had a protein concentration of 0.08 mg/mL. Abdolshahi et al. (2021) determined that *Bacillus* sp. strain LA12 exhibited a phytase enzyme activity of 4.5 U/mg and had a total protein of 780 mg as a result of partial purification.

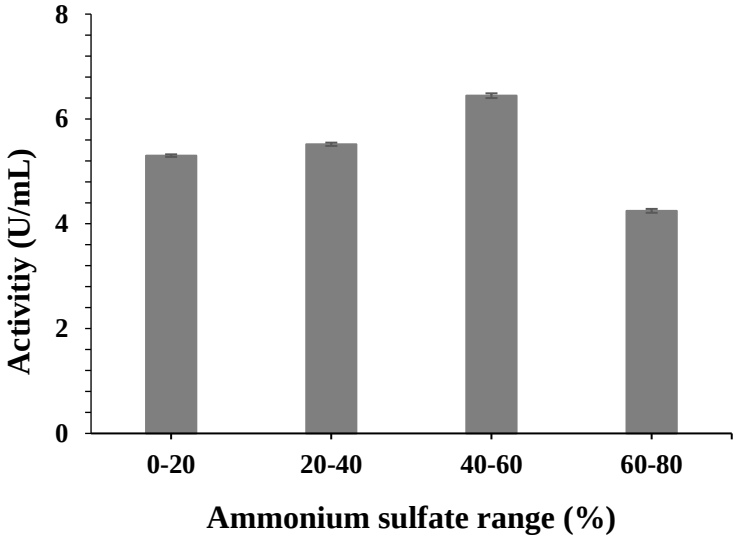


Figure 1. Ammonium sulphate precipitation ranges of phytase enzyme

In order to determine the pH value at which the phytase of *B. wiedmannii* ND44 showed optimum activity, activity measurements were performed at different pH values (pH 2.0-11.0) and the highest activity was observed at pH 5.5 (Figure 2). Similar to our study, Abdolshahi et al. (2021) found that the pH value at which the phytase enzyme purified from *Bacillus* sp. strain LA12 showed optimum activity was pH 5.5. Sardar et al. (2022) determined the pH value at which the phytase of *Bacillus* sp. (HCYL03) isolated from soil showed optimum activity as pH 5. Different from our study; Trivedi et al. (2022) reported that the phytase purified from *B. subtilis* P6 strain showed optimum activity at pH 6 in their study. Javaid et al. (2022) determined the pH range in which the extracellular phytase of *B. subtilis* KT004404 showed optimum activity as pH 6.5- 7.0. Sanni et al. (2023) reported that the phytase enzyme purified from *B. cereus* showed optimum activity at pH 7. When the literature studies and the findings of the present study are considered, it is seen that the phytase enzyme purified from *Bacillus* sp. is generally acidic. Furthermore, the optimum pH value is enzyme specific and may vary depending on the type and source of the phytase enzyme.

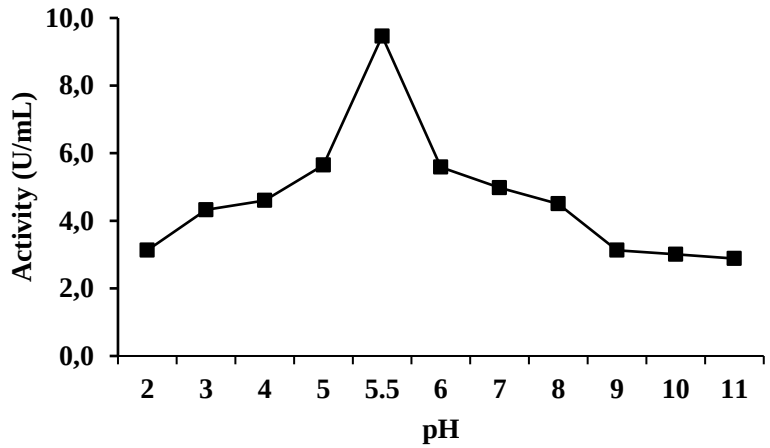


Figure 2. Effect of pH on activity of phytase enzyme

In order to determine the temperature at which the phytase of *B. wiedmannii* ND44 showed optimum activity, the reaction was measured at 10°C intervals in the range of 15-85°C. The temperature at which the enzyme showed optimum activity was determined as 55 (Figure 3). Abdolshahi et al. (2021) determined the temperature value at which the phytase purified from *Bacillus* sp. strain LA12 showed optimum activity as 60 °C. Javaid et al. (2022) reported that the phytase enzyme purified from *B. subtilis* KT004404 showed optimum activity at 40 °C. Sardar et al. (2022) found that the temperature at which phytase purified from *Bacillus* sp. (HCYL03) showed maximum enzyme production was 45°C. Trivedi et al. (2022) found that the temperature at which the phytase enzyme of *B. subtilis* P6 showed optimum activity was 40 °C. It was determined that the phytase enzyme purified from *B. cereus* isolated from Achatina fulica by Sanni et al. (2023) showed optimum activity at 50°C. Considering the literature studies, phytase enzyme purified from *Bacillus* sp. generally shows optimum activity under thermophilic conditions in the range of 40-60 °C.

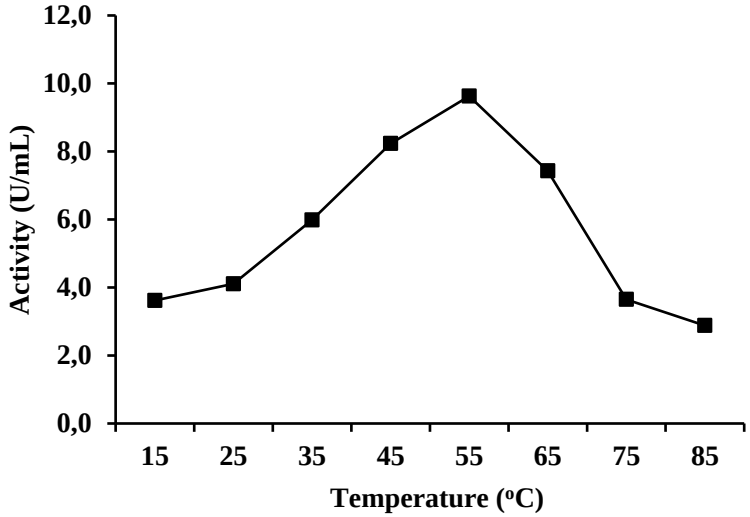


Figure 3. Effect of temperature on activity of phytase enzyme

When the phytase of *B. wiedmannii* ND44 was tested against sodium phytate, K_m and V_{max} values of the enzyme were 0.016 mM and 4.14 µmol/min, respectively (Figure 4). Abdolshahi et al. (2021) found K_m and V_{max} values of phytase of *Bacillus* sp. strain LA12 as 0.197 mM and 1.174 µmol/min, respectively. Javaid et al. (2022) determined the kinetic parameters of phytase purified from *B. subtilis* KT004404 as K_m: 0.175 mM and V_{max}: 250 U/mL. Sanni et al. (2023) determined K_m and V_{max} values of phytase enzyme purified from *B. cereus* as 0.11 mM and 55.6 µmol/min/mL, respectively. In the present study, the low Km value reveals that the enzyme shows a high binding tendency towards its substrate and the enzyme-substrate complex is easily formed. This is important in terms of showing that the enzyme can work effectively even at low substrate concentrations.

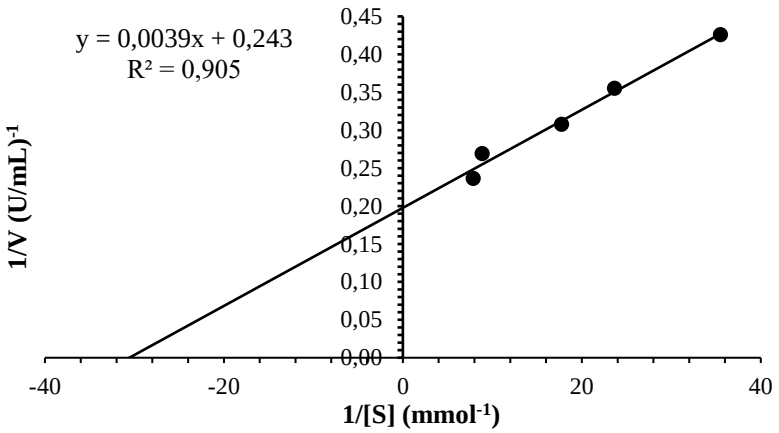


Figure 4. Graph to determine the kinetic parameters (K_m and V_{max}) of phytase for phytate

Conclusion and Recommendations

In conclusion, the results indicate that phytase partially purified from *B. wiedmannii* ND44 strain isolated from field soil exhibits optimum activity under acidic and thermophilic conditions. Thanks to these properties, the purified phytase enzyme can contribute to increase the bioavailability of phytate phosphorus, especially in animal nutrition, as well as various biotechnological applications in the food and environmental sectors. The obtained findings reveal that phytase is a powerful biocatalytic agent that can be evaluated in terms of environmental sustainability and industrial efficiency. Therefore, further experimental studies are needed to better understand the phytase production potential of microorganisms isolated from different sources and to elucidate the biochemical properties of these enzymes in detail.

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ALTERNATIVE LANDSCAPE DESIGNS TO REDUCE URBAN HEAT ISLAND FORMATION; THE EXAMPLE OF SİVAS CITY SQUARE

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ABSTRACT

UN World Urbanisation Reports reveal that the rate of urbanisation is increasing on a global scale and the population density in cities is gradually rising. The urbanisation process leads to the transformation of ecosystems, reduction of natural areas and environmental sustainability is increasingly under threat. Especially the increase in the rate of construction and the shrinkage of green areas directly affect the climatic structure of cities and accelerate the formation of urban heat islands. This situation causes a decrease in thermal comfort in cities, an increase in heat stress and negative consequences on public health. Studies reveal that green areas in the city offer more favourable microclimatic conditions compared to structural textures and play a stabilising role on the urban ecosystem. Accordingly, it is becoming increasingly important to develop alternative green space solutions to reduce climatic impacts and increase the comfort of urban life.

In this study, it was aimed to create a basis for ENVI-met analyses by producing climate sensitive vegetative landscape design scenarios for Sivas City Square. Different vegetative landscape design scenarios that will adapt to the climatic conditions of the city, integrate with natural vegetation, improve the visuality of the city square and increase thermal comfort are proposed. The plants selected within the scope of the study consist of species that are resistant to the climate of Sivas and compatible with the urban ecosystem.

The proposed design approaches aim to provide aesthetic and functional solutions in the urban space by supporting the microclimatic structure of the square. At the same time, it is aimed to increase the quality of use of the square with design decisions that improve the bioclimatic comfort of the city residents. Design decisions that are compatible with the urban texture, have high aesthetic value and emphasise functionality are shaped in a way to support the environmental and structural features of the square.

Keywords: ENVI-met, climate, urbanisation, thermal comfort, UHI

KENTSEL ISI ADASI OLUŞUMUNU AZALTICI ALTERNATİF PEYZAJ TASARIMLARI; SİVAS KENT MEYDANI ÖRNEĞİ

ÖZET

BM Dünya Şehirleşme Raporları, küresel ölçekte kentleşme hızının arttığını ve kentlerdeki nüfus yoğunluğunun giderek yükseldiğini ortaya koymaktadır. Kentleşme süreci, ekosistemlerin dönüşmesine, doğal alanların azalmasına ve çevresel sürdürülebilirliğin giderek daha fazla tehdit altına girmesine neden olmaktadır. Özellikle yapılaşma oranının yükselmesi ve yeşil alanların daralması, kentlerin iklimsel yapısını doğrudan etkileyerek kentsel ısı adası oluşumunu hızlandırmaktadır. Bu durum, kentlerde termal konforun azalmasına, sıcaklık stresinin yükselmesine ve halk sağlığı üzerinde olumsuz sonuçlar doğmasına sebep olmaktadır. Araştırmalar, kent içerisindeki yeşil alanların, yapısal dokulara kıyasla daha elverişli mikroklimatik koşullar sunduğunu ve kent ekosistemi üzerinde dengeleyici bir rol oynadığını ortaya koymaktadır. Bu doğrultuda, iklimsel etkileri azaltmak ve kent yaşamının konforunu artırmak amacıyla alternatif yeşil alan çözümlerinin geliştirilmesi giderek daha fazla önem kazanmaktadır.

Bu çalışmada, Sivas Kent Meydanı için iklim duyarlı bitkisel peyzaj tasarım senaryoları üretilerek, ENVI-met analizlerine altlık oluşturulması amaçlanmıştır. Kentin iklim koşullarına uyum sağlayacak, doğal bitki örtüsü ile bütünleşen, kent meydanının görselliğini iyileştirerek termal konforunu arttırmaya yönelik farklı bitkisel peyzaj tasarım senaryoları önerilmiştir. Çalışma kapsamında seçilen bitkiler, Sivas'ın iklimine dayanıklı, kentsel ekosisteme uyumlu türlerden oluşmaktadır.

Önerilen tasarım yaklaşımları, meydanın mikroklimatik yapısını destekleyerek, kentsel mekânda estetik ve fonksiyonel çözümler sunmayı amaçlamaktadır. Aynı zamanda, kent sakinlerinin biyoklimatik konforunu iyileştiren tasarım kararlarıyla meydanın kullanım kalitesinin artırılması hedeflenmektedir. Kent dokusuna uyumlu, estetik değeri yüksek ve fonksiyonelliği ön plana çıkaran tasarım kararları, meydanın çevresel ve yapısal özelliklerini destekleyecek biçimde şekillendirilmiştir.

Anahtar Kelimeler: ENVI-met, iklim, kentleşme, termal konfor, kentsel ısı adası

1. GİRİŞ

İklim değişikliği, insan faaliyetleri sonucunda ortaya çıkan karbon emisyonlarının küresel ölçekte atmosferde birikmesiyle dünya enerji dengesini değiştirmekte ve ekosistemler üzerinde kalıcı etkiler bırakmaktadır (Hornsey ve Fielding, 2020). Hükümetlerarası İklim Değişikliği Paneli (IPCC) tarafından yayımlanan 6. Değerlendirme Raporu (2022), mevcut sera gazı seviyelerinin ve emisyon eğilimlerinin 2040 yılına kadar dünya çapında daha sert iklim olaylarına yol açacağını öngörmektedir. Bu süreç, kentlerin ormansızlaşması, biyoçeşitliliğin azalması, iklim sistemindeki dönüşümler ve kentsel ısı adalarının güçlenmesi gibi birçok önemli çevresel değişime sebep olmaktadır (IPCC, 2022; Türkeş, 2022).

Özellikle kentleşmenin hızla artması, kentsel alanların doğal peyzaj öğelerinden uzaklaşarak betonlaşmış geçirimsiz yüzeylerin artmasına ve kentsel ısı adası (KIA) etkisinin güçlenmesine neden olmaktadır (Daemei vd., 2018). Yeşil alanların azalması, buharlaşma ve terleme süreçlerinin zayıflaması ve kentsel yüzeylerde sıcaklığın tutulması, kentlerde biyoklimatik konforun düşmesine ve halk sağlığını tehdit eden ısı stresinin artmasına yol açmaktadır (Oke, 1982; Grimmond ve Oke, 1991; Yılmaz,2019).

Dünya nüfusunun yaklaşık %55'i kentlerde yaşamaktadır ve 2050 yılına kadar bu oranın %70'e ulaşacağı öngörülmektedir (UNDESA, 2023; WHO, 2023). Kentleşme eğilimleri arttıkça, kentlerin iklim sistemi üzerindeki baskısının daha büyük bir sorun haline gelmesi kaçınılmazdır (IPCC, 2022). Bununla birlikte, kentlerde ısıl konforun sağlanması, kentsel planlama ve sürdürülebilirlik stratejileri açısından kritik bir gereklilik olarak öne çıkmaktadır.

Kentsel ısı adası, yapılı çevrelerin etkisiyle kentlerde sıcaklıkların kırsal alanlara göre daha yüksek olmasına sebep olmaktadır (Oke, 1982; Arnfield, 2003; Streutker, 2003). Mikroiklim etkileri, özellikle binaların konumu, yapı yüzeylerinde kullanılan malzemeler ve kent içi yeşil alanların eksikliği gibi faktörlerden doğrudan etkilenmektedir. Yapılan çalışmalar, ağaçların ve yeşil alanların kentsel ısı adası etkisini hafifletmede önemli bir rol oynadığını ortaya koymaktadır (Allegrini vd., 2012; Altunkasa, 2019; Yılmaz, 2019).

Yeşil alanlar, kentlerin termal konforunu artırarak, enerji tasarrufu sağlamakta, hava kalitesini iyileştirmekte ve kentsel mekanların yaşanabilirliğini desteklemektedir (Steemers, 2003; Fahmy ve Sharples, 2009; Lin vd., 2010). Planlı peyzaj tasarımlarının kent içindeki mikroiklimi olumlu yönde etkilediği ve özellikle su yüzeylerinin serinletici bir rol oynadığı belirlenmiştir (Jin vd., 2005; Bowler vd., 2010; Gunawardena vd., 2017).

Kentlerde alternatif yeşil alanların oluşturulması, suyun etkin kullanımı, hava kalitesinin artırılması ve doğal bitki türlerinin kent ekosistemine entegre edilmesi, kentsel sürdürülebilirlik açısından kritik faktörlerdir (Güneroğlu, 2018; Yılmaz vd., 2019; Oğuztürk, 2023). Planlı yeşil alan tasarımı, yalnızca kent estetiğine değil, aynı zamanda termal konforun iyileştirilmesine ve ısı stresinin azaltılmasına da doğrudan katkı sağlamaktadır. Rüzgar akışının yönlendirilmesi, gölgeleme etkisi, su yüzeylerinin mikroiklim dengesi gibi unsurlar, kentlerde biyoklimatik konforun sürdürülebilir şekilde sağlanmasında büyük önem taşımaktadır (Hsieh vd., 2016; Kong vd., 2017,).

Bu çalışmada, Sivas Kent Meydanı'nın mikroklimatik yapısını desteklemek ve kent ekosistemine uyumlu bir peyzaj tasarımı oluşturmak amacıyla farklı bitkisel tasarım senaryoları önerilmektedir. Kentin iklim koşullarına uygun olarak belirlenen bitki türleri, meydanın hem görsel hem de ekolojik işlevini iyileştirmeye yönelik tasarlanmıştır.

Önerilen peyzaj senaryoları, kent meydanında doğal çevre ile entegre, estetik ve fonksiyonelliği ön plana çıkaran bitkisel düzenlemeler içermektedir. Yeşil alanların

mikroklimatik etkilerinden faydalanılarak, kent sakinlerinin termal konforunun artırılması ve meydanın kullanım kalitesinin yükseltilmesi amaçlanmaktadır.

Kentsel mikroiklim analizlerinde bilimsel temeller sunan ENVI-met modeli, kent içi malzeme yüzeyleri, bitki yoğunluğu ve hava akışı gibi unsurları değerlendirerek, farklı tasarım senaryolarının biyoklimatik konfor üzerindeki etkisini ölçmektedir (Bruse vd., 1998; Ng vd., 2012). Modelin sunduğu detaylı simülasyonlar, kent meydanları, parklar ve yeşil alanların planlanmasında termal stresin azaltılmasına yönelik veri sağlamaktadır.

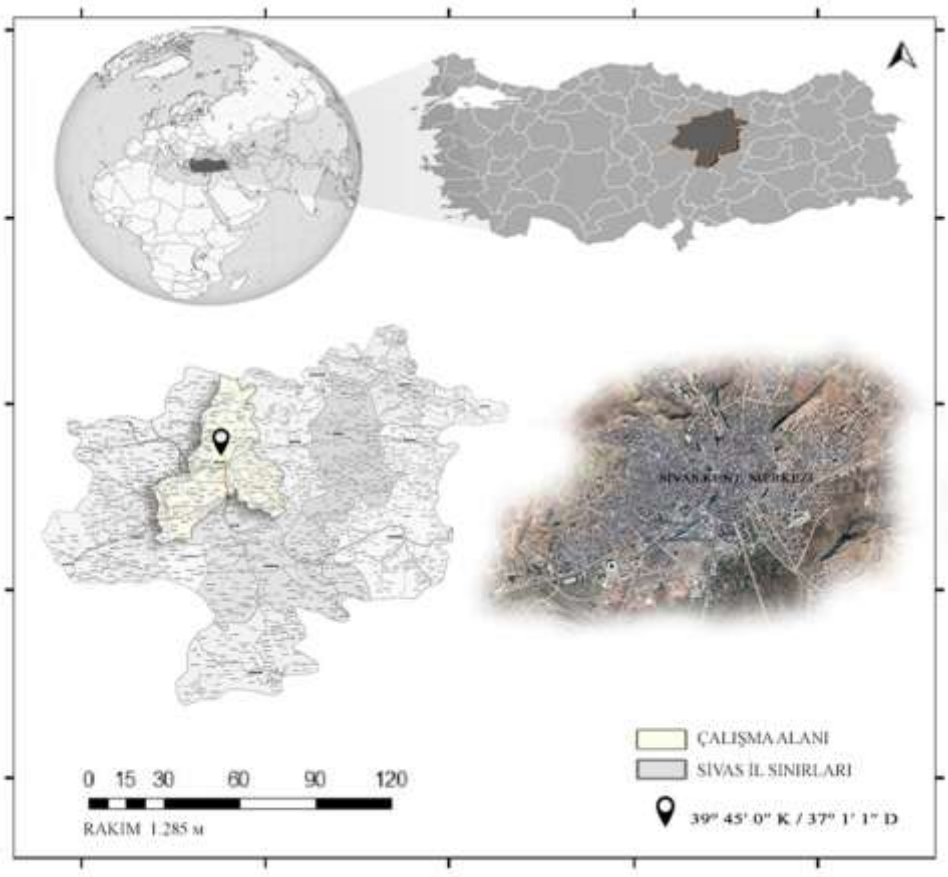
Çalışmada önerilen tasarım yaklaşımları, ilerleyen süreçlerde mikroklimatik simülasyonlarla test edilebilecek şekilde yapılandırılmış olup, ENVI-met analizleri için bilimsel bir temel oluşturmayı ve kentsel alanlarda biyoklimatik konforun artırılmasına katkı sağlamayı hedeflemektedir

2. MATERYAL VE YÖNTEM

Materyal

Bu çalışmanın materyalini Sivas Tarihi Kent Meydanı oluşturmaktadır.

Sivas, İç Anadolu Bölgesi'nin Yukarı Kızılırmak Havzası'nda yer almakta olup Türkiye'nin yüz ölçümü açısından en büyük ikinci ili konumundadır. 36° ve 39° doğu boylamları ile 38° ve 41° kuzey enlemleri arasında bulunan kent, doğuda Erzincan, batıda Yozgat, güneyde Malatya ve Kahramanmaraş, kuzeyde Ordu ve Tokat, kuzeydoğuda Giresun ve güneybatıda Kayseri illeri ile çevrilidir (Demiroğlu ve Memlük, 2015). (Şekil 1 de Sivas iline ait coğrafi konum ve Şekil 2'de çalışma alanına ait görsel verilmiştir.)



Şekil 1. Sivas kenti coğrafi konumu



Şekil 2. Çalışma alanı görseli (URL-1)

Sivas Kent Meydanı ve Tarihî Özellikleri

Sivas Kent Meydanı, tarihî dokusu ve kültürel yapıları ile kent yaşamının merkezinde yer almaktadır. Anadolu'nun ortasında geniş bir coğrafyaya sahip olan Sivas, tarih boyunca birçok uygarlığa ev sahipliği yapmıştır. Hititler, Romalılar, Bizanslılar gibi medeniyetlerin hâkimiyetinde kalan kent, Türklerin Anadolu'ya gelişi ile birlikte Türk kültürünün önemli merkezlerinden biri haline gelmiştir (Anonim, 2018).

Kent meydanı, Selçuklu dönemine ait medreseler, anıtsal yapılar ve kamu binalarıyla çevrili olup, tarih boyunca sosyal, kültürel ve ticari etkileşimin merkezi olmuştur. Sivas Kongresi'nin düzenlendiği şehir olması nedeniyle, Cumhuriyet'in temellerinin atıldığı kentlerden biri olarak da öne çıkmaktadır. (Şekil 3'te meydanın yapısı verilmiştir.)



Şekil 3. Tarihi Kent Meydanı (1-Şifaiye Medresesi, 2-Çifte Minareli Medrese, 3- Buruciye Medresesi, 4- Kale Cami, 5-Hamam Kalıntısı, 6- Hükümet Konağı, 7- Jandarma Binası, 8-Atatürk Anıtı, 9- 4 Eylül Kongre Binası, 10- Belediye Hizmet Binası, 11- Aynalı Çarşı, 12-Meydan Havuzu (URL-2).)

Sivas, Anadolu'nun önemli ulaşım merkezlerinden biri olup, hava, kara ve demiryolu bağlantıları açısından stratejik bir konuma sahiptir. Ankara-İstanbul, Erzincan-Erzurum ve Samsun ticaret yolları, kentin ulaşım ağının başlıca unsurlarını oluşturmaktadır (Taşabat, 2006).

Sivas, karasal iklim özelliklerine sahip olup, kış aylarında uzun süre kar örtüsü altında kalmakta, yaz aylarında ise sıcak ve kurak hava koşulları görülmektedir (ÇED ve Çevre İzinleri Şube Müdürlüğü, 2017).

Kent ekosistemi, doğal bozkır vejetasyonu ile ormansal bitki örtüsü arasında bir geçiş niteliği taşımaktadır. Bölgede yayılış gösteren bitki türleri kısa ömürlü ve kuraklığa dayanıklı olup, yaz aylarında kuru bir görünüme sahiptir (Ergün, 2016).

Kentin yüksek kesimlerinde ***Pinus nigra*** (karaçam), ***Pinus sylvestris*** (sarıçam), ***Fagus orientalis*** (kayın), ***Juniperus communis*** (ardıç) türleri yayılış gösterirken, kent merkezinde yapılan peyzaj çalışmalarında ***Tilia cordata*** (ıhlamur), ***Acer negundo*** (akçaağaç), ***Platanus orientalis*** (doğu çınarı) gibi bitkiler tercih edilmektedir (Zeren vd., 2017).

Yöntem

Bu çalışma kapsamında kullanılan yöntemler, veri toplama süreci, alan içerisinde mikroklimatik ölçümlerin yapılması ve bitkisel peyzaj tasarım senaryolarının oluşturulması olmak üzere üç ana başlık altında ele alınmıştır.

1- Veri Toplama

Çalışmada kullanılan veriler, literatür taraması, saha gözlemleri ve kent meydanının mevcut peyzaj yapısının incelenmesi yoluyla elde edilmiştir. Kentsel ekosistem üzerine yapılan akademik çalışmalar analiz edilerek, mikroklimatik konforu artırmaya yönelik peyzaj tasarım ilkeleri belirlenmiştir.

2- Alan İçinde 24 Saatlik Sıcaklık Ölçümü Yapılması

Araştırma alanında (Sivas Kent Meydanı'nda), 15.08.2024 tarihinde, belirlenen bir noktada, anemometre cihazı kullanılarak mikroklimatik veriler ölçülmüştür. 24 saat süren ölçüm sürecinde saatlik sıcaklık değerleri kaydedilmiş olup, gündüz saatleri sıcaklığı ortalaması 31.4 °C olarak hesaplanmıştır ve en yüksek sıcaklık değeri saat 13:00'de 39.4 °C olarak belirlenmiştir.

3- İklimi İyileştirmeye Yönelik Bitkisel Peyzaj Tasarım Senaryoları

Önerilen bitkisel peyzaj düzenlemeleri, kent meydanının mevcut dokusu korunarak oluşturulmuştur ve alanın mevcut bitkisel yapısı incelenmiştir.

Meydan için önerilen bitkisel tasarım senaryolarında, bitki türleri Sivas'ın iklim koşullarına dayanıklı, ekolojik sistemle uyumlu ve görsel açıdan estetik değer taşıyan bitkiler arasından seçilmiştir. Bitki seçim sürecinde şu kriterler dikkate alınmıştır:

- Kentsel mikroklimatik etkilere dayanıklılık
- Buharlaşma yoluyla soğutma etkisi
- Kentsel ekosistem ile uyum
- Gölgelik oluşturma kapasitesi

Çalışma kapsamında üç farklı bitkisel peyzaj tasarım senaryosu geliştirilmiştir:
- Yoğun Ağaçlandırma Senaryosu: Gölgelik alanların artırılması, termal konforun iyileştirilmesi.
- Su Kullanımı ve Az Yoğun Ağaçlandırma Senaryosu: Su yüzeyleri ile mikroklimatik denge sağlama.
- Çalı ve Az Yoğun Ağaçlandırma Senaryosu: Çalı gruplarıyla ekolojik dengeyi sağlarken yüzey sıcaklıklarını düşürme

Çizim ve modelleme süreci:

- AutoCAD ile teknik çizimler oluşturulmuştur.
- SketchUp Pro ile 3D modelleme yapılmıştır.
- Lumion ile görselleştirme ve render alma işlemleri gerçekleştirilmiştir

3. BULGULAR

Kent meydanında önerilen bitkisel peyzaj senaryoları, kent ekosistemine uyumlu bitki türlerini seçerek hem termal konforu artırma hem de mekânsal kimliği koruma stratejisini temel almaktadır. Her senaryo, kentsel mikroklimayı düzenleyerek kent sakinlerinin çevresel konforuna katkı sunmayı hedeflemektedir.

SENARYO 1: Yoğun Ağaçlandırma Bitkisel Tasarımı

Bu senaryoda, kent meydanında maksimum gölge alan oluşturulması ve sıcaklık dengesinin korunması hedeflenmiştir. Geniş yapraklı ve yüksek gölgelik etkisi bulunan ağaç türleri tercih edilerek kent sakinlerinin termal konforunu artırma amaçlanmıştır (Şekil 4; Şekil 5).



Şekil 4. Yoğun ağaçlandırılmış bitkisel tasarım (Senaryo 1)



Şekil 5. Bitkisel tasarım görselleri, (Senaryo 1)

Bu tasarım yaklaşımı, kent meydanında yoğun bitkisel örtü oluşturmayı öngörerek yüzey sıcaklıklarının düşürülmesine ve hava akışının optimize edilmesine katkı sağlayabilir (Menteş ve Yılmaz, 2025). Gölgelik alanların artırılması, özellikle yaz aylarında meydan kullanıcıları için konforlu mekanlar oluşturulmasını destekleyebilir. Ayrıca, su buharlaşması ve yaprak yüzeylerinden gerçekleşen doğal soğutma etkileri sayesinde sıcaklık kontrolünün sağlanabileceği öngörülmektedir (Jandaghian ve Colombo, 2024).

Seçilen Bitkiler ve Mikroklimatik Etkileri:

Tilia cordata (Ihlamur): Yoğun gölgelik oluşturarak yüzey sıcaklıklarını düşürür ve su buharlaşması yoluyla serinletici etki sağlar.

Betula pendula (Huş Ağacı): Dikey yapısı ile güneş ışığını kırarak sıcaklık stresini azaltır.

Malus floribunda (Süs Elması) ve ***Pyrus calleryana*** (Süs Armudu): Estetik ve mikroklimatik katkı sunarak yeşil alanın ekolojik işlevselliğini artırır.

Acer platanoides 'Globosum' (Çınar Yapraklı Top Akçaağaç)***:*** Kentsel peyzajda mikroklimatik stabiliteyi destekleyerek uzun vadeli ekolojik sürdürülebilirlik sağlar (Şekil 6).



Şekil 6. Senaryo 1 tasarımında kullanılan bitkilerin görselleri (URL-3)

Senaryo kapsamında tarihi yapılara yaklaştıkça bitki boyları bilinçli olarak küçültülerek, kent dokusunun korunması ve tarihi yapıların görünürlüğünün artırılması amaçlanmıştır.

SENARYO 2: Su Kullanımı ve Az Yoğunlukta Ağaçlandırma Bitkisel Tasarımı

Bu senaryoda, bitkisel peyzaj ile su yüzeyleri bir araya getirilerek mikroklimatik denge sağlanması hedeflenmiştir. Ağaçların yoğunluğu belirli noktalarda azaltılarak, meydanın odak noktalarında su yüzeyleri kullanılmıştır (Şekil 7; Şekil 8).



Şekil 7 . Az yoğun ağaçlandırma ve su kullanımı tasarımı (Senaryo 2)



Şekil 8. Bitkisel tasarım görselleri (Senaryo 2)

Su yüzeyleri, kentsel alanlarda doğal bir serinletici etki sağlayarak, sıcaklık stresinin azalmasına katkıda bulunmaktadır (Menteş ve Yılmaz, 2025). Bu strateji doğrultusunda, kent meydanında farklı mikroklimatik unsurların bir araya getirilmesiyle termal konforun iyileştirilmesi hedeflenmektedir.

Seçilen Unsurlar ve Mikroklimatik Etkileri :
Platanus acerifolia ve Platanus orientalis (Çınar Ağacı): Geniş yaprakları ile gölge sağlar ve serinletici etki oluşturur.
Su yüzeyleri: Buharlaşma etkisi sayesinde çevresel serinletme sağlar ve hava dolaşımını optimize eder.
Ekolojik sistem uyumu: Su yüzeyleri ile uyumlu bitki türlerinin seçilmesiyle kentsel sürdürülebilirlik hedeflenmiştir (Şekil 9).



Şekil 9. Senaryo 2 tasarımında kullanılan bitkilerin görselleri (URL-4).

Bu senaryoda, kent meydanının odak noktalarında su yüzeyleri ile bitkisel tasarımın entegre edilmesi, mekânsal estetik ve mikroklimatik etkilerin optimize edilmesi açısından önemli bir potansiyel taşımaktadır (Jandaghian ve Colombo, 2024).

SENARYO 3: Çalı ve Az Yoğunlukta Ağaçlandırma Bitkisel Tasarımı

Bu senaryoda ise, ağaç yoğunluğu dengelenerek çalı gruplarıyla mikroklimatik dengenin desteklemesi hedeflenmiştir. Daha düşük boyutlu bitki türleri ile hava dolaşımı düzenlenerek ve yüzey sıcaklıkları üzerinde dengeleyici bir etki beklenmektedir (Tamaskani Esfehankalateh vd., 2021), (Şekil 10; Şekil 11; Şekil 12).



Şekil 10. Çalı ve az yoğunlukta ağaçlandırma bitkisel tasarımı (Senaryo 3)



Şekil 11. Bitkisel tasarım görselleri (Senaryo 3)



Şekil 12. Bitkisel tasarım görselleri (Senaryo 3)

Bitki yoğunluğunun dengelenmesiyle birlikte, kentsel tasarımda kent ekosistemiyle uyumlu bitkiler tercih edilerek sürdürülebilir yeşil alanlar oluşturulmuştur. Bu senaryoda kent sakinlerinin kullanımı için dinlenme ve geçiş noktaları göz önünde bulundurularak, görsel ve ekolojik açıdan dengeli bir peyzaj yapısı kurgulanmıştır.

Seçilen Bitkiler ve Mikroklimatik Etkileri:

Cornus alba (Süs Kızılcığı): Estetik ve dirençli çalı türü, kentsel ekosistemi destekler.

Viburnum opulus (Kartopu): Çiçeklenme dönemi ve ekolojik katkılarıyla kentsel peyzajı güçlendirir.

Juniperus spp. (Ardıç): Sivas'ın iklimine dayanıklı, kuraklık stresine dirençli, ekolojik sürdürülebilirliği destekleyen bitki türü (Şekil 13).



Şekil 13. Senaryo 3 tasarımında kullanılan bitkilerin görselleri (URL-5).

4. SONUÇ VE ÖNERİLER

Kentleşme sürecinin hızlanmasıyla birlikte, ekosistemlerin dönüşümü ve doğal alanların azalması kentlerin mikroklimatik dengesini bozarak kentsel ısı adasının artmasına ve insan sağlığının olumsuz etkilenmesine yol açmaktadır**. Yeşil alanların kent içindeki yetersizliği, bu sürecin en önemli nedenlerinden biri olarak öne çıkmaktadır (Cui vd., 2016; Yılmaz ve Öztürk, 2023).**

Kent meydanları, **mikroklimatik konforun sağlanması ve kentsel ekosistemin dengelenmesi açısından kritik öneme sahiptir** (Bruse vd., 1998; Ng vd., 2012). Yeşil alanlar, **hava sıcaklığını düzenleyerek, güneş ışığını filtreleyerek ve su buharlaştırma yoluyla çevresel serinletme sağlayarak** kent içerisindeki sıcaklık stresini azaltmaktadır (Güneroğlu, 2018).

Bu çalışma kapsamında, **Sivas Kent Meydanı'nda önerilen bitkisel peyzaj senaryoları ile,** kentsel ısı adası etkisini azaltarak termal konforu sağlamak **ve kent kimliğiyle uyumlu bir yeşil altyapı oluşturma**k amaçlanmıştır. **Mevcut yapı korunarak**, kentsel peyzajın **mikroklimatik etkilerini güçlendirecek** bitkisel tasarım senaryoları üretilmiştir. Önerilen senaryolarda bitkisel peyzaj düzenlemeleri ve su yüzeylerinin kullanımı ile kentsel termal konforun artırılması hedeflenmiştir.

Yapılan araştırmalar, ağaç gölgelik oranının %15 artırılmasının sıcaklığı 2.0 °C'ye kadar düşürebileceğini göstermektedir (Middel vd., 2015). Ayrıca, kent ölçeğinde yapılan çalışmalarda, bitki örtüsünün ve gölgeleme etkisinin kentsel ısı adasını azaltıcı bir rol oynadığı tespit edilmiştir (Shashua-Bar vd., 2010; Lin vd., 2010; Meier ve Scherer, 2012; Antoszewski vd., 2020).

Su yüzeyleri de kentsel ısı adası etkisini azaltmada önemli bir rol oynamaktadır. Yapılan araştırmalar, su yüzeylerinin hava sıcaklığını yaklaşık 2.5 °C düşürebileceğini ortaya koymaktadır (Jin vd., 2005; Bowler vd., 2010; Gunawardena vd., 2017).

Bu doğrultuda üretilen bitkisel peyzaj tasarım senaryolarının (Yoğun Ağaçlandırma Senaryosu, Su Kullanımı ve Az Yoğun Ağaçlandırma Senaryosu, Çalı ve Az Yoğun Ağaçlandırma Senaryosu) Sivas Kent Meydanı'nda kentsel ısı adası etkisini azaltarak termal konforu artıracağı ve sıcaklığı 2-3 °C'ye kadar düşürebileceği öngörülmektedir. Alan düzenlemeleri, tarihi dokunun korunması esas alınarak gölgeleme etkisi dengeli bir şekilde oluşturulmuş, bitkisel peyzaj tasarımında mekânın fonksiyonel ve estetik değerleri öncelikli olarak ele alınmıştır.

İlerleyen süreçlerde, önerilen tasarım yaklaşımları mikroklimatik simülasyonlarla değerlendirilebilir ve ENVI-met analizleri ile bilimsel olarak incelenerek, kentsel alanlarda biyoklimatik konforun artırılmasına yönelik katkılar sunabilir.

Belediyelerin önerilen peyzaj tasarım senaryolarını daha geniş alanlara uygulamasıyla kentsel ısı adası etkisini azaltabileceği ve kentin termal konforunu iyileştirebileceği öngörülmektedir. Ayrıca, daha çok yeşil alanın kentlerin peyzaj değerine katkı sağlamasının yanı sıra, kentlerin termal konforunu iyileştireceği düşünülmektedir.

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EFFECTS OF SOLARIZATION AND FUMIGANT APPLICATIONS ON WILT AND ROOT ROT DISEASE IN TOMATO

DOMATESTE SOLGUNLUK VE KÖK ÇÜRÜKLÜĞÜ HASTALIĞINA SOLARİZASYON VE FUMİGANT UYGULAMALARININ ETKİLERİ

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ÖZET

Seracılık, dünya genelinde özellikle tropikal ve subtropikal bölgelerde önemli bir ekonomik faaliyet olup, domates gibi yüksek değerli sebzeler bu üretimin önemli bir parçasıdır. Ancak, serada fungal hastalıklar, özellikle toprak kökenli patojenler, verimde kayıplara ve kalitede düşüşlere yol açmaktadır. Dikim öncesi toprak fumigasyonu, toprak kaynaklı zararlıları kontrol etmek için kullanılan yaygın bir yöntemdir. Bu çalışmada, seralarda domateste solgunluk ve kök çürüklüğüne neden olan toprak kökenli patojenler (*Fusarium oxysporum ve Rhizoctonia solani*) ile mücadelede, solarizasyon ve solarizasyon ile metam potasyum fumigantının azaltılan dozlarının etkileri araştırılmıştır. Araştırma, 2020 yılında Mersin ilinin Tarsus ve Akdeniz ilçelerinde yer alan 2 farklı domates serasında yürütülmüştür. Tarsus/Mersin ve Yenitaşkent-Akdeniz/Mersin seralarında yapılan denemelerde, solarizasyon ve solarizasyon + metam potasyum fumigantının azaltılan dozları (45, 60, 75 ve 100 L/da) uygulanmıştır. Denemelerde, kullanılan fumigant dozlarının hastalık çıkışını azaltmada % 68,9 ile %93,3 etkili olduğu yalnızca solarizasyon uygulamasının ise %54,46 ile %43,38 arasında etki sağlandığı belirlenmiştir. Solarizasyon uygulamaları ile her iki denemede de önemli bir hastalık kontrolü sağlanmış, ancak solarizasyon+fumigant uygulamaları daha yüksek etki göstermiştir. Özellikle solarizasyon +75 L/da dozunda metam potasyum uygulamasında, hastalık çıkışını etki %92,42-%93.3 olarak belirlenmiştir. Sonuçlar, solarizasyon + azaltılan dozlarda metam potasyum uygulamalarının toprak kökenli hastalıkların kontrolünde etkili olduğunu göstermektedir. Ayrıca, hasatta yapılan verim değerlendirmelerinde kontrole göre solarizasyon + azaltılan dozda fumigant uygulanan parsellerden 1,2- 2,1 kg/m^2 fazla verim elde edilmiştir.

Anahtar Kelimeler: Toprak kökenli patojenler, solarizasyon, metam potasyum, domates, sera

1. GİRİŞ

Seracılık, dünya çapında sebze üretiminin önemli bir kısmını oluşturmakta ve bu üretim, genellikle iklim koşullarından bağımsız olarak yapılan örtü altı tarımını kapsamaktadır. Domates, seracılıkta yetiştirilen en yaygın sebzelerden biridir ve yüksek pazar değeri ile çiftçilerin gelirini artırmaktadır. Ancak, sera ortamlarında toprak kökenli hastalıklar ciddi verim kayıplarına neden olabilir. Bu patojenler, özellikle domates gibi ekonomik değeri yüksek bitkilerde, kök hastalıklarına yol açarak bitkilerin gelişimini olumsuz yönde etkiler (Yücel ve ark., 2015).

Sürekli aynı toprağa aynı ürünün ekilmesi, ürün verimini, kalitesini ve çiftçi gelirini azaltan toprak kaynaklı hastalıklarda artışa yol açan önemli faktörlerdir (Liu ve ark.,2022). Köklerin ve gövdelerin fide aşamasındaki enfeksiyonu genellikle %20~30 ürün azalmasına neden olur, ancak hastalık şiddetli olduğunda %50~60 ürün kaybına veya hastalık çok şiddetli olduğunda %100 ürün kaybına yol açabilir (Cao ve ark. 2022). Üreticilerin toprak kaynaklı hastalıkları kontrol etmede yaşadığı zorluk, Türkiye'de yüksek değerli ürünlerle ekilen alanların genişlemesini kısıtlamıştır. Özellikle *Fusarium oxysporum*, *Rhizoctonia solani* gibi patojenler, kök çürüklüğü ve solgunluk gibi hastalıklara yol açarak bitki sağlığını tehdit etmektedir (Bhat et al., 2015). Bu etmenlerle mücadele için yaygın olarak kimyasal ve biyolojik yöntemler kullanılmakta, ancak bu yöntemlerin etkinliği, hastalıkların yayılma hızına ve çevresel faktörlere bağlı olarak değişkenlik gösterebilmektedir. Seralarda, bu tür hastalık etmenlerine karşı etkili bir mücadele, ekim öncesi toprak dezenfeksiyonu ile sağlanabilir. Solarizasyon uygulaması toprak kökenli fungal patojenlerin kontrol altına alınmasında kullanılan yaygın bir yöntemdir. Geleneksel kimyasal fumigantlar, hızlı ve etkili bir çözüm sunsa da çevresel etkileri, insan sağlığı üzerindeki potansiyel zararları ve yüksek maliyetler gibi sorunlar bu yöntemlerin kullanımını sınırlamaktadır. Son yıllarda, çevre dostu alternatiflerin geliştirilmesi önemli bir araştırma konusu olmuştur. Solarizasyon, güneş enerjisi ile toprağın sıcaklığını arttırarak patojenleri öldürmeyi amaçlayan çevre dostu bir yöntemdir (Hansen et al., 2007). Bununla birlikte, metam potasyum içeren kimyasal fumigantlar, toprağın mikroorganizma ve patojenik yükünü hızla azaltabilen etkili bir yöntem olarak öne çıkmaktadır. Dikim öncesi toprak fümigasyonu, sebzelerde toprak kaynaklı fungal patojenleri, nematodları ve yabani otları kontrol etmek için yaygın olarak uygulanmaktadır. Fumigantlar genellikle yüksek değerli ürünlerin toprak kaynaklı patojenlerini kontrol etmek için kullanılır, ancak hedef olmayan toprak mikroorganizmalarını da etkilemektedir. Kloropikrin (CP), 1,3-dikloropropen (1,3-D) veya metam bazlı ürünler (metam sodyum ve metam potasyum) gibi toprak fumigantları, toprak kaynaklı hastalıkları kontrol etmek ve verimi artırmak için yaygın olarak kullanılmaktadır (Locascio ve ark., 2014; Zhang ve ark., 2019; Li ve ark., 2021). Günümüzde kullanılan fumigantlar, Ozon tabakasına zarar vermesi nedeniyle 2015 yılında küresel olarak yasaklanan metil bromürün (MB) yerini almışlardır (UNEP, 2000). Yapılan çalışmalar geniş spektrumlu fumigant uygulamalarının toprak mikrobiyomu üzerindeki etkileri yoluyla dolaylı olarak bitki verimliliğindeki artışı desteklediğini gösterirken özellikle fumigant uygulamasından sonraki ilk dört hafta boyunca hedef olmayan toprak mikrobiyal topluluklarının bolluğunu, çeşitliliğini ve bileşimini etkileyebileceğini de ortaya koymuştur (Khatri ve ark., 2021; Zhu ve ark., 2020; Yu ve ark., 2019, 2021a, 2021b; Castellano-Hinojosa ve ark., 2022). Üreticiler, MB ün kullanımdan kaldırılmasından sonra çeşitli fumigant alternatifleri uygulamaya çalışmışlardır. Alternatif fumigant uygulamalarının toprak kökenli fungal patojenleri kontrol ederken bitki büyümesini ve verimliliğini artırmak ve geliştirmek yetiştiriciler için büyük önem taşımaktadır.

Bu çalışma, domates yetiştiriciliğinde toprak dezenfeksiyonu için solarizasyon ve metam potasyum içeren fumigantın yalnız ve azaltılan dozda birlikte uygulanmasının etkinliklerini

karşılaştırarak, daha sürdürülebilir ve verimli yöntemlerin belirlenmesini ve ülke çiftçimizin kullanımına sunmayı amaçlamaktadır.

2. MATERYAL VE METOT

Denemeler, 2020 yılı yaz döneminde bir önceki üretim dönemi sonunda kök hastalıkları ile bulaşık olduğu belirlenen Tarsus/Mersin ve Yenitaşkent-Akdeniz/Mersin'deki 2 domates serasında yürütülmüştür. Denemede kullanılan ilaçlar ve dozları Çizelge 1' de verilmiştir.

Çizelge 1. Domateste solgunluk ve kök çürüklüğü hastalığına karşı sera koşullarında denemeye alınan ilaçlar ve dozları

İlacın Ticari Adı	Firması	Etkili Madde Adı / Yüzdesi ve Formülasyonu	Dozu L /da
Tamifume 690	Platin Kimya Mümessillik ve Dış Ticaret A.Ş.	Metam Potassium ***690*** g/l SL	45, 60,75,100

Deneme bloklara (şerit parsellere) uygulama şeklinde yapılmış, tekrarlar her blok içinde alınmıştır. Her uygulama dozu için seranın farklı yerinde 2 bloka uygulama yapılmıştır. Metam potasyum fumigantının (MP) ruhsatlı dozu 125L/da olduğu için solarizasyon ile kombinasyonu uygulamalarında 100, 75, 60, 45 L/da dozlar alınmıştır. Deneme desenine göre 6 karakter (yalnız solarizasyon uygulaması (S), S +MP 45 L/da, S+ MP 60 L/da, S+ MP 75 L/da, S+ MP 100L/da ve Kontrol) ve 4 tekrarlı olacak şekilde düzenlenmiştir. Deneme parselleri yaklaşık 40 m^2 alınmıştır. Parsellere yaklaşık 100 Alaturka F1 çeşidi domates fidesi dikilmiş ve her parselden 25 bitki değerlendirilmeye alınmıştır. Parsel aralarında 2 sıra emniyet şeridi bırakılmıştır. Deneme yapılan Tarsus serasında toprak yapısı kumlu-tınlı olup, pH değeri 7.2, organik madde oranı ise %1.6'dır. Yenitaşkent serası ise hafif alkali toprak yapısına sahip olup, pH değeri 7.8, organik madde oranı ise %2.1 olarak belirlenmiştir. Solarizasyon uygulaması Temmuz ayında uygulanmış, 4 hafta sonra fumigant uygulamaları, damla sulama sistemi ile örtü altından yapılmıştır. 2 hafta sonra örtüler açılmış havalandırmadan sonra fide dikimi yapılmıştır. Toprak sıcaklıkları veri kaydediciler (Onset Computer Corporation, Bourne, MA, ABD) tarafından kaydedilmiştir. Hobolar parsellerde 5, 10 ve 20 cm derinliğe yerleştirilmiştir.

Verim Değerlerinin Alınması

Denemelerde farklı uygulamalarının yapıldığı parsellerden ve kontrol parselinden domates meyveleri toplanarak tartılmış, elde edilen kasa sayılarından kg/m^2 olarak toplam verim hesaplanmıştır.

Uygulamaların patojenler üzerine etkilerinin belirlenmesi

Uygulamaların toprak kökenli fungal patojenler *Fusarium oxysporum ve Rhizoctonia solani* ve hastalık oranı üzerindeki etkilerini belirlemek amacıyla vegetasyon dönemi sonunda dikimden yaklaşık 5,5 ay sonra 11.02.2020 tarihinde her parselden ortadaki 25 domates bitkisi sökülerek hasta veya sağlam olarak değerlendirme yapılmıştır. İletim demetlerinde renk bozukluğu görülen bitkiler hasta olarak değerlendirilmiştir (Şekil.1). Bu bitkilerden fungal izolasyon çalışması yapılarak hastalığa neden olan etmenler belirlenmiştir.



Şekil 1. İletim demetlerinde ve köklerde görülen renk değişikliği

Fungal Patojenlerin İzolasyon Çalışmaları

Her iki deneme alanından alınan hastalıklı bitkilerin kök kökboğazı ve gövdelerinden izolasyonlar yapılmıştır. Bunun için 5-6 mm büyüklüğünde kesilen infekteli dokular %2'lik sodyum hipoklorit (NaOCl) içerisinde yüzeysel olarak dezenfekte edildikten sonra 2 kez steril distile su ile durulanarak steril kurutma kağıtları üzerinde 15-20 dakika kurutulmuştur. Daha sonra bu dokular, içerisine 250 mg/L dozunda streptomicine eklenen PDA (Patates Dekstroz Agar) ortamına ekilmiş ve bu petriler 24 °C sıcaklıkta 4-5 gün süreyle karanlıkta inkübe edilmiştir. İnkübasyon süresi sonunda gelişen kolonilerden mikroskobik teşhisler yapılmıştır. Elde edilen funguslardan saflaştırma yapılmış ve PDA eğiklerinde, +4°C'de saklanmıştır.

İstatistik analiz

Uygulama yapılan parsellerde hasta bitki sayısının toplam bitki sayısına oranlanması ile hastalık oranları bulunmuş ve Abbot uygulanarak ilaçların yüzde etkileri saptanmış, açı değerleri karşılıklarına F testi uygulanarak ilacın dozları arasındaki farklılıklar ortaya konulmuştur.

3. BULGULAR

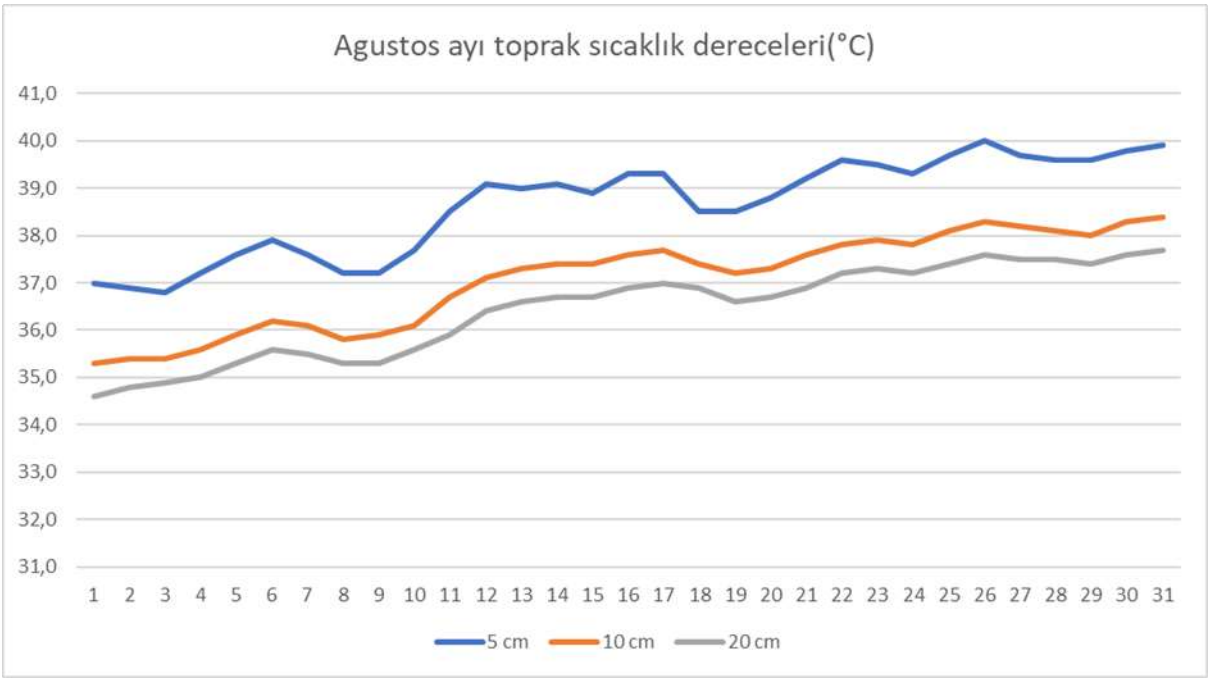
Toprak kaynaklı patojenler ve hastalık oranı üzerindeki uygulamaların etkileri

Hastalık belirtileri gösteren bitkilerden yapılan izolasyon çalışmaları sonucunda *Fusarium oxysporum ve Rhizoctonia solani* fungusları tespit edilmiştir. Denemeye alınan fumigant dozlarının ve solarizayon uygulamasının hastalık çıkışına etkileri Çizelge 2 de verilmiştir. Yenitaşkent bölgesinde yürütülen denemede Solarizasyon uygulamasının hastalık çıkışına etkisi %54,46 olarak belirlenmiştir. Ancak, solarizasyon + metam potasyum uygulamaları, özellikle 75 L/da dozunda, en yüksek etkinliği göstermiş ve etki %92,42 olmuştur. Metam potasyum fümigantının 100 L/da dozunda ise hastalık çıkışına etki oranı %92,71'olarak belirlenmiştir. Tarsus bölgesinde de benzer sonuçlar elde edilmiştir. Solarizasyon uygulamasında hastalık çıkışına etki oranı %43,38 bulunurken, solarizasyon+ fumigant uygulamaları, yine en yüksek etkiyi göstermiş ve solarizasyon+ 75 L/da dozundaki metam potasyum uygulamasında etki %93,30olarak belirlenmiştir. Fumigantın 100 L/da uygulaması ise etki benzer oranda %92,71'bulunmuştur.

Çizelge 2. Yenitaşkent ve Tarsus deneme seralarında uygulamalar ve elde edilen etkiler(%)

Uygulamalar	Yenitaşkent Etki (%)	Tarsus Etki (%)
Solarizasyon	54,46 d	43,38 c
Sol+MP 45 L/da	77,3 c	68,9 b
Sol+MP 60 L/da	85,48 b	79,76 ab
Sol+MP 75 L/da	92,42 a	93,3 a
Sol+MP 100 L/da	92,71 a	92,71 a

Deneme alanından hobolar ile elde edilen sıcaklık değerlerine bakıldığında (Şekil 2) en yüksek toprak sıcaklığı(40 °C) solarizasyon uygulaması yapılan parsellerde 10-20 cm derinlikte elde edilirken en düşük toprak sıcaklık değeri(34,8 °C) ise uygulama yapılmayan kontrol parsellerinde elde edilmiştir. *Fusarium oxysporum* un 30 dk. ıslak ısıtmada 57.5-60 °C de canlılığını kaybettiği Shlevin ve ark. (2012) tarafından bildirilmiştir.



Şekil 2. Deneme alanlarından alınan sıcaklık değerleri

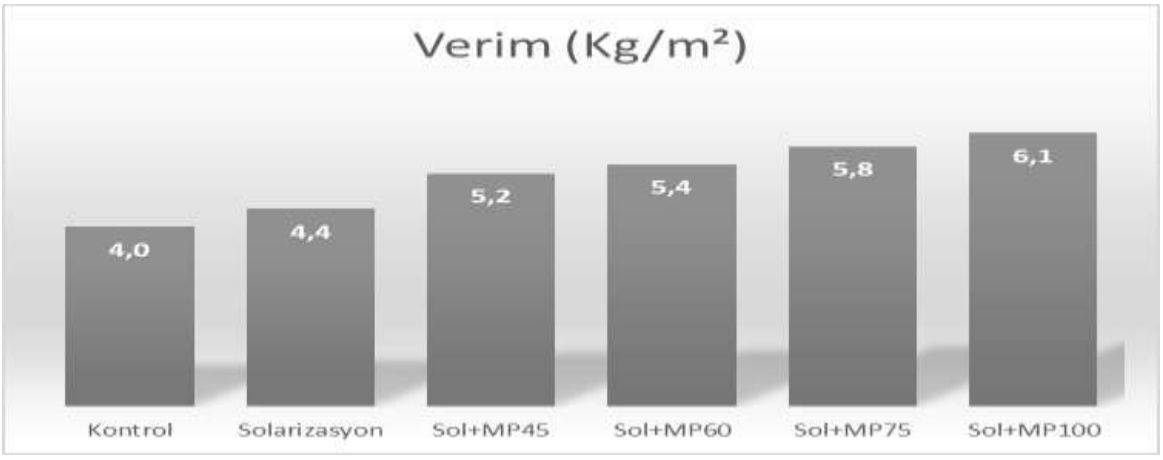
Bu çalışmada da sadece solarizasyon uygulamasının domateste solgunluk ve kök çürüklüğü hastalığı etmenleri *F. oxysporum* ve *R. solani* yi elemine etmede yeterli etkiyi sağlayamadığı ancak Sol+MP 75 uygulamasının daha etkili sonuçlar verdiği belirlenmiştir (Şekil 3).



Şekil 3. Solarizasyon uygulaması ve uygulama parsellerinde hastalıklı ve sağlıklı domates bitkileri

Verim Değerleri

Domateste toprak kökenli patojenlerin dezenfeksiyonu amacıyla yapılan farklı uygulamalarda, Kontrol, Sol, Sol+MP 45, Sol+MP 60, Sol+MP 75, Sol+MP100 elde edilen ortalama verim değerleri Şekil 4'de verilmiştir. Kontrol uygulamalarında 4,0 kg/m^2 ürün alınırken, hastalığı kontrol etmede de en yüksek etkiyi gösteren Sol+MP 75 ve Sol+MP 100 uygulamalarında sırasıyla 5,8 kg/m^2 ve 6, 1 kg/m^2 ürün elde edilmiştir. Günümüze kadar yapılan çalışmalarda, solarizasyon uygulamasının domateste verimi arttırmaya yardımcı olduğu (Kumar vd. 2002) ve solarizasyonun fumigantlar ile kombinasyonunun soğanda hastalık çıkışını azaltıp verimi arttırdığı bildirilmiştir (Hartz vd., 1989).



Şekil 4. Deneme alanı seralardan alınan domates verim sonuçları (kg/m^2)

4. TARTIŞMA

Solarizasyonun toprak kökenli fungal patojenler üzerindeki etkisi; iklim, toprak koşulları ve topraktaki fungal propagüllerin dağılımını gibi çok sayıda değişkene bağlıdır (Pullman ve ark. 1979). Solgunluk hastalıklarının (*Fusarium* spp.) toprak solarizasyonuyla baskılanması büyük

ölçüde birçok üründe ve farklı deneysel koşullarda araştırılmıştır (Gamliel ve Katan1993). Domates Fusarium solgunluk hastalığı, Florida'daki (Chellemi ve ark. 1997), İsrail'deki (Gamliel ve Katan 1993) ve Türkiye'deki (Yücel ve Çınar 1989) tarla denemelerinde toprak solarizasyonu ile başarılı bir şekilde kontrol edilmiştir. Ancak bu etkinin toprağın ilk 5 cm derinliğinde olduğu ve fungal popülasyonu azaltmak için başka uygulamaların da gerektiği ortaya konulmuştur (Chellemi ve ark. 1994).

Toprak dezenfeksiyonu, seracılıkta hastalıkların kontrolü açısından kritik öneme sahiptir. Solarizasyon, çevre dostu ve ekonomik bir yöntem olmasına rağmen, fumigantlarla karşılaştırıldığında daha düşük etkinlik göstermektedir. Metam potasyum içeren fumigant, özellikle domates yetiştiriciliği gibi ekonomik olarak değerli ürünlerde daha verimli bir çözüm sunmaktadır Fumigantların etkinliği, kullanılan doz ile doğru orantılıdır ve bu uygulama dozunun doğru belirlenmesinin önemini vurgulamaktadır. Bu tür kimyasal uygulamaların çevresel etkileri ve kullanım maliyetleri göz önünde bulundurulduğunda solarizasyon daha çevre dostu ve düşük maliyetli bir alternatif olarak, özellikle düşük patojen yoğunluğu olan alanlarda tercih edilebilir.

Her iki denemede de solarizasyon+ Metam potasyum uygulamasının 75L/da dozunda en yüksek etkinliği sağladığı ve hastalık çıkışına etki oranlarının %92'lerin üzerinde olduğu görülmüştür. Solarizasyon uygulamasının yalnız uygulanmasıyla her iki bölge için de belirgin bir etki sağlansa da fumigant uygulamalarına kıyasla daha düşük etkili olduğu, önceki sezonda serada hastalık çıkışı yüksekse yalnız solarzaisyon uygulaması yerine ruhsatlı dozu 125L/da olan fumigantın azaltılan dozu(75L/da) ile kombine edilerek uygulanmasının yeterli etkiyi sağladığı görülmüştür.

Sonuçlar, fumigantların daha etkili olduğunu göstermektedir, ancak solarizasyonun toprak dezenfeksiyonunda ekonomik ve çevresel açıdan sürdürülebilir bir yöntem olduğu göz önünde bulundurulduğunda, daha yüksek etki için fumigantların azaltılan dozları ile uygulanmasının, entegre mücadele stratejilerinin oluşturulmasının gerektiği kanısına varılmaktadır.

5. SONUÇ VE ÖNERİLER

Bu çalışmada elde edilen veriler, solarizasyon ve metam potasyum içeren fumigantların azaltılan dozları ile kombinasyonunun domates seralarında toprak kökenli hastalıkların (*Fusarium oxysporum ve Rhizoctonia solani)* kontrolünde etkili bir yöntem olduğunu göstermektedir. Özellikle yüksek dozda(125L/da) uygulanan Metam potasyum fumigantının azaltılan dozunun(75 L/da) solarizasyon ile kombinasyonunun, hastalık çıkışına etkisi %92.42-%93,30'olarak belirlenmiştir. Solarizasyon ve metam potasyum içeren fumigantların toprak dezenfeksiyonundaki etkinliklerini karşılaştırıldığında fumigantların özellikle yüksek dozlarda daha fazla etkinlik sağladığı görülmekle birlikte, çevreye olan olası etkileri göz önünde bulundurularak dikkatli bir şekilde kullanılması gerekmektedir. Solarizasyon ise daha ekonomik ve çevre dostu bir alternatif olup, özellikle düşük dozlarda fumigantlarla kombinasyon halinde daha verimli sonuçlar verdiği sonucuna varılmıştır.

TEŞEKKÜR

Çalışmada destek sağlayan Platin Kimya Mümessillik ve Dış Ticaret A.Ş. teşekkür ederiz.

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PLANT PROTECTION PROBLEMS AND THE STATUS OF CHEMICAL CONTROL IN POTATO IN TURKEY

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ABSTRACT

Potatoes play an important role as one of the world's staple foods. Potato is a strategic product in the agricultural sector, attracting attention for its nutritional value and various industrial uses. Potato production is also an important agricultural activity that contributes to rural development, both economically and socially. Although potato is grown almost everywhere in Turkey, the provinces of Niğde, Afyonkarahisar and Konya form the backbone of the country's production. The potato production process poses serious phytosanitary biotic risks. In addition to diseases caused by bacterial, fungal and viral agents, plant parasitic nematodes and entomological pests are problems that require continuous monitoring and intervention in production areas. Likewise, broadleaf and narrowleaf weeds are other factors that need to be controlled because of their competitive power and their potential as disease vectors. In this context, various chemical products are used within the framework of the plant protection policy in force in Turkey. The registered pesticides are grouped according to the target organisms and these groups include insecticides, fungicides, bactericides, nematicides and herbicides. In this study, the main bacterial, fungal, viral and phytoplasma diseases, nematodes, insect pests and common weed species encountered in potato production in Turkey and the current status of the registered plant protection products used against them are reviewed.

Keywords: potato, chemical control, plant protection products, Turkey

TÜRKİYE'DE PATATESTE YAŞANAN BİTKİ KORUMA SORUNLARI VE KİMYASAL MÜCADELESİNİN DURUMU

ÖZET

Patates, dünya genelinde temel besin kaynaklarından biri olarak önemli bir rol oynamaktadır. Hem besleyici değeri hem de çeşitli endüstriyel kullanım alanlarıyla dikkat çeken patates, tarım sektöründe stratejik bir üründür. Ayrıca patates üretimi hem ekonomik hem de sosyal yönüyle kırsal kalkınmaya katkı sağlayan önemli bir tarımsal faaliyettir. Türkiye'nin hemen her yerinde patates yetiştiriciliği yapılmakla beraber Niğde, Afyonkarahisar ve Konya illeri ülke genelinde üretimin omurgasını oluşturmaktadır. Patates üretim süreci, bitki sağlığı açısından ciddi biyotik riskler taşımaktadır. Bakteriyel, fungal ve viral etmenlerin neden olduğu hastalıkların yanı sıra entomolojik zararlılar bitki paraziti nematodlar üretim alanlarında sürekli izleme ve müdahale gerektiren sorunlardır. Aynı şekilde, dar ve geniş yapraklı yabancı otlar da hem rekabet gücü hem de hastalık etmenlerine vektör olma potansiyelleri nedeniyle mücadele edilmesi gereken diğer unsurlar arasında yer almaktadır. Bu kapsamda, Türkiye'de yürürlükte olan bitki koruma politikaları çerçevesinde, çeşitli kimyasal ürünler kullanımda bulunmaktadır. Ruhsatlı pestisitler, hedef organizmalara göre gruplandırılmakta; bu gruplar arasında insektisit, fungisit, bakterisit, nematisit ve herbisitler yer almaktadır. Bu çalışmada Türkiye'de patates yetiştiriciliğinde karşılaşılan başlıca bakteriyel, fungal, viral ve fitoplazma kökenli hastalıkları; ayrıca nematodları, böcek zararlılarını ve yaygın yabancı ot türleri ile bu etmenlere karşı kullanılan ruhsatlı bitki koruma ürünlerinin güncel durumunu incelemektedir.

Anahtar kelimeler: patates, kimyasal mücadele, bitki koruma ürünleri, Türkiye

1. GİRİŞ

Artan dünya nüfusu ile birlikte gıdaya olan talep sürekli artmakla birlikte azalan tarım arazileri ve iklim değişikliği gibi faktörlerin etkisi ile mevcut tarım sistemi bu talebi karşılamada yetersiz kalabilmektedir. Patates, dünya genelinde temel besin kaynaklarından biri olarak önemli bir rol oynamaktadır. Hem besleyici değeri hem de çeşitli endüstriyel kullanım alanlarıyla dikkat çeken patates, tarım sektöründe stratejik bir ürün durumundadır.

Tarihsel olarak, patatesin kökeni Güney Amerika'ya dayanmaktadır. İlk olarak And Dağları'nda keşfedilen patates, yerel halk tarafından yetiştirilmiş ve tüketilmiştir. İspanyol kaşifler tarafından 16. yüzyılda Avrupa'ya getirilen patates, zamanla dünya genelinde popülerlik kazanmış ve önemli bir tarım ürünü haline gelmiştir. Patatesin dayanıklılığı ve besin değeri, özellikle 18. ve 19. yüzyıllarda Avrupa'da açlıkla mücadelede önemli bir rol oynamıştır. Patates ana vatanı olan Güney Amerika'dan İspanyol gemiciler tarafından Avrupa'ya getirilirken sadece basit bir gıda olmadığını kanıtlamış ve kıtlık sorunuyla karşı karşıya olan Kuzey Avrupa'yı tarihten silinmekten kurtarmıştır. Bu sayede normalleşme, zenginleşme ve şehirleşme başlamıştır. Patates içerdiği karbonhidrat miktarı tahıllardan 4 kat daha fazla olduğu için insanlar doymakta kolaylık yaşamış ve nüfus artışları görülmeye başlamıştır. Bu gıda maddesi tarihte bu denli öneme sahip yerini hala korumaya devam etmektedir (Reader, 2008).

Temel gıda ürünü olan patatesin kullanım alanlarının yaygınlaşması ve dünya nüfusunun artması patatese olan talebi ve tüketimi hızlı bir şekilde arttırmaktadır. Bu bakımdan dünyada en çok üretimi yapılan bitkisel ürünler sıralamasında şeker kamışı, mısır, pirinç, buğday, yağlı palmiye meyvesinden sonra patates altıncı sırada gelmektedir (FAOSTAT, 2023). Dünya genelinde insanların beslenmesi ve geçimi açısından en önemli tarımsal faaliyetlerden biri olarak öne çıkan patates tüm dünyada geniş bir coğrafyada üretilen ve tüketilen bir bitkidir. Dünya genelinde patates üretimi, güney yarım küredeki ülkelerden başlayarak, kuzeydeki soğuk iklimlere kadar uzanan geniş bir alana yayılmıştır. Özellikle Avrupa, Kuzey Amerika, Asya ve Afrika'nın birçok bölgesinde patates üretimi yoğun bir şekilde gerçekleşmektedir (Devaux ve ark., 2014).

Gerek çeşitlilik gerekse de sayı açısından en büyük familyalardan biri olan ve 3000'in üzerinde türü içeren Solanaceae familyası içinde yer almaktadır (Knapp ve ark., 2004). Solanaceae ailesinde yer alan ve önemli bir besin kaynağı olan yumru kökleriyle bilinen patatesin dünya genelinde farklı iklim ve toprak koşullarında yetişebilen çok çeşitli türleri bulunmaktadır (Erdoğan, 2018). Dünya genelinde 163 ülkede yetiştirilen patates tahıllar dışındaki en önemli ürün olup, 370 milyon tonluk üretimiyle dünyada sırasıyla mısır, çeltik ve buğdaydan sonra en çok yetiştirilen dördüncü temel gıda kaynağı durumundadır (FAOSTAT, 2023). Açlık ve yoksullukla mücadelede en umut verici bitkisel ürünlerden biri olarak kabul edilen patates, artan nüfus ve gıda talebi nedeniyle FAO tarafından gıda güvenliği ürünü olarak tavsiye edilmektedir (Thomas ve Sansonetti, 2009). Patates üretimi açısından çok uygun koşullara sahip olan ve hemen her yerinde patates üretilen Türkiye'de 139.072 ha alanda patates yetiştirilmekte ve 5,2 milyon tonluk üretim yapılmaktadır (FAOSTAT, 2023). Ülkemizde patatesin en iyi yetişebileceği yerler 650 metrenin üzerindeki yüksek yaylalardır. Sırasıyla Niğde, Afyonkarahisar, Konya, Kayseri, İzmir, Sivas, Nevşehir illeri en çok patates yetiştirlen iller olup Türkiye patates üretiminin %60'ını karşılamaktadırlar (TUİK, 2023).

Yaklaşık 10 000 yıl önce tarımın başlangıcından bu yana, yetiştiriciler insan kullanımı ve tüketimi için yetiştirilen bitkisel ürünler için zararlı organizmalarla mücadele etmek zorunda kalmıştır (Oerke, 2006). Bu kayıplar sadece ürün kayıpları ile sınırlı kalmamış aynı zamanda sosyal ve ekonomik etkileri de söz konusu olmuştur (Savary ve ark., 2006). Tarihsel olarak en

dikkate değer olanlar arasında belki de ilk sırada Batı Avrupa'daki patates geç yanıklığı (*Phytophthora infestans*) salgını yer almaktadır (Bourke, 1964). Kuzey Amerika'dan Avrupa'ya 1845 yılında yayılan etmen İrlanda'da Büyük Kıtlığa ve Avrupa'nın geri kalanında ciddi ürün kayıplarına yol açmıştır (Yoshida ve ark., 2013). Etmen İrlanda'da 1845'te ekilen patateslerin %40'ını, sonraki yıl tamamını yok etmiştir. İrlanda nüfusu kıtlık sona erdiğinde %20-25 oranında eksilmiştir (Bourke, 1964). Bu nedenle bitki koruma, artan gıda kalitesi ve miktarı talebinin karşılanmasında bariz bir role sahiptir (Strange ve Scott 2005). Hastalık, zararlı ve yabancı otlar tarımsal üretim üzerinde küresel ölçekte %20 ila 40'ı arasında değişen oranlarda kayıplara neden olmaktadır (Teng ve Krupa 1980; Teng 1987; Oerke ve ark. 1994; Oerke 2006). Hastalık ve zararlılardan kaynaklanan ürün kayıplarının doğrudan olduğu kadar dolaylı, bazılarının kısa bazılarının ise uzun vadeli sonuçlar doğuran bir dizi etkileri vardır (Zadoks 1967). Bu nedenle "%20 ila %40 arasında kayıp" ifadesi, ürün kayıplarının tüketicilere, kamu sağlığına, toplumlara, çevreye, ekonomik dokulara ve çiftçilere olan gerçek maliyetini yeterince yansıtmamaktadır. Bitki koruma uygulamaları, %12'si hastalıklara, %8'i zararlılara ve %8'i yabancı otlara bağlı olmak üzere toplam %50'lik potansiyel kayıpları yaklaşık %29'luk gerçek kayıplara indirmiş olmakla beraber önlenen bu kayıpların çok büyük bir kısmı pestisit uygulamaları sonucunda sağlanabilmiştir (Oerke, 2006).

Bu çalışmada patates bitkisi yetiştiriciliğinde sorun olan hastalık, zararlı ve yabancı otlar ile bunların mücadelesinde kullanılan ve ülkemizde ruhsatlı olan pestisitler hakkında bilgi verilmeye çalışılmıştır.

2. DÜNYA'DA VE TÜRKİYE'DE PATATES ÜRETİMİ

Patates, hem taze tüketim hem de tarımsal sanayiye hammadde sağlama kapasitesiyle, dünya genelinde ekim ve üretim alanlarını giderek daha da sağlamlaştıran önemli bir tarım ürünüdür. Artan dünya nüfusu ve sınırlı tarım arazileri göz önünde bulundurulduğunda, birim alandan yüksek verim sağlaması ve daha geniş bir kitleye hitap edebilecek besleyici özelliklere sahip olması nedeniyle patates, günümüzde gıda güvencesi açısından küresel ölçekte önem arz eden ürünlerden biri olarak değerlendirilmektedir (Anonim, 2021).

Ülkelere göre dünya patates ekim alanları incelendiğinde 2022 yılında ekim alanı en fazla olan ülke 5.723.449 ha'lık alanla Çin olup ardından sırasıyla Hindistan ve Ukrayna gelmektedir. Patates ekim alanında Türkiye 139.072 ha'lık alanla 22. sırada yer almaktadır. Ülkelere göre dünya patates üretim miktarları incelendiğinde de ilk üç sıralama değişmezken Türkiye 5.200.000 ton patates üretimiyle 15. sırada yer almaktadır. Dünya patates verim ortalaması 2106 kg/da olup 5086 kg/da ile Yeni Zelenda ilk sırada yer alırken 4908 kg/da ile ABD ve 4421 kg/da ile Danimarka en yüksek üretim yapan ülkeler listeye girmiştir. Türkiye 3739 kg/da ile 13. sırada yer almaktadır (FAOSTAT, 2023). Son beş yıllık verilere bakıldığında, dünya genelindeki patates ekim alanlarında kayda değer bir değişiklik gözlemlenmemektedir. Ancak iklim koşullarındaki değişiklikler ve tarımsal teknolojilerdeki ilerlemeler, birim alandan elde edilen verimin artmasını sağlamıştır. Artan nüfus yoğunlukları dikkate alındığında, patates üretiminde verimlilik daha da kritik bir hale gelmiştir. Özellikle Çin ve Hindistan gibi hızla büyüyen nüfuslara sahip ülkeler, artan besin talebini karşılayabilmek adına daha geniş tarım alanlarına ihtiyaç duymaktadır (Anonim, 2021).

Türkiye'de patates üretimi, 1925 yılında yaklaşık 73.000 ton düzeyindeyken günümüzde yaklaşık 5,5 milyon tona ulaşarak önemli bir gelişme göstermiştir. Yaklaşık 150 yıllık bir geçmişe sahip olan patates, Türkiye'nin en önemli tarım ürünlerinden biridir. Üretimi, sanayisi, pazarlaması ve tüketimi birbirinden bağımsız olarak gelişen ayrı sektörler haline gelmiştir (Çalışkan ve ark., 2010). Türkiye, patates üretimi açısından son derece uygun coğrafi koşullara

sahiptir; bu nedenle 81 ilin yaklaşık 75'inde patates üretimi yapılmaktadır. Orta, kuzey ve kuzeydoğu bölgeler, ılıman iklim özellikleri sayesinde yaz döneminde patates üretimi için elverişli alanlardır. Akdeniz ve Ege bölgelerinde ise hâkim olan Akdeniz iklimi sayesinde kış ve ilkbahar başlarında birinci ürün, yaz sonu ve sonbaharda ise ikinci ürün olarak patates yetiştirilebilmektedir. Bu iklim çeşitliliği, Türkiye'de yıl boyunca patates üretiminin mümkün olmasını sağlamaktadır (Çalışkan ve ark., 2010). 2022 yılı verilerine göre, Türkiye'de patates ekim alanları açısından Niğde 176,3 bin dekar (%12,7) ile ilk sırada yer alırken, Afyonkarahisar yaklaşık 150 bin dekar (%10,8) ile ikinci, Konya ise 120,5 bin dekar (%8,7) ile üçüncü sıradadır. Sivas ilinde ise 2018 yılında 169.737 ton olan patates üretimi, 2022 yılında 334.435 tona çıkarak %97 oranında bir artış göstermiştir (TUİK, 2023). Ancak son beş yıllık dönemde ekim alanlarında dalgalanmalar yaşanmıştır. Bu azalışların başlıca nedenleri arasında patates siğili hastalığı (*Synchytrium endobioticum*) yayılımı, yağış düzensizlikleri, fiyat istikrarsızlıkları ve artan girdi maliyetleri sayılabilir.

3. PATATES ÜRETİMİNDE KARŞILAŞILAN SORUNLAR

Patates üretimi, yüksek getiri potansiyeline sahip olmasına rağmen, çeşitli zorluklarla karşı karşıyadır. Bu zorluklar, tarımsal verimliliği düşürmekte, üretim maliyetlerini artırmakta ve çiftçilerin ekonomik durumunu olumsuz etkilemektedir. İşte Türkiye'de patates üretiminde sıklıkla karşılaşılan başlıca sorunlar:

3.1. Depolama Sorunları

Patatesin hasat sonrası depolanması sırasında birçok problem yaşanabilmektedir. Depolama sorunları, özellikle uzun süreli saklama gereken durumlarda büyük kayıplara yol açmakta olup depo koşullarının uygun olmaması, ürünlerin %10-20 oranında kaybına yol açmaktadır.

3.2. Pazarlama ve Fiyat Dalgalanmaları

Patates fiyatlarının dalgalı bir seyir izlemesi, çiftçilerin üretim planlamasında belirsizlik yaratmaktadır. Üretimdeki fazlalık, fiyatların düşmesine neden olurken, üretim azlığı fiyatları yükseltmekte ve fiyat dalgalanmaları üreticilerin gelirlerinde istikrarsızlığa yol açmaktadır. Tüccar ve aracılar, fiyatları manipüle ederek üreticinin düşük gelir elde etmesine sebep olabilmekte ve çiftçilerin doğrudan pazar erişimi sınırlamaktadır.

3.3. Girdi Maliyetleri

Üretim için gerekli olan girdilerdeki maliyet artışı, çiftçilerin kâr oranlarını düşürmektedir. Gübre fiyatlarındaki sürekli artış, çiftçilerin yeterli miktarda gübre kullanmasını engellemekte ve zararlılarla mücadelede kullanılan pestisitler, küçük ölçekli üreticiler için ekonomik yük oluşturmaktadır.

3.4. Tohumluk Patates:

Kaliteli tohumluk patateslerin fiyatı yüksektir. Bu durum, bazı üreticilerin düşük kaliteli tohum kullanmasına neden olmaktadır.

3.5. Enerji ve Su Maliyetleri:

Sulama sistemleri için elektrik ve su maliyetleri yüksek olduğu için çiftçiler sulama yaparken kısıtlama yoluna gidebilmektedir.

3.6. Tarımsal Bilgi ve Teknoloji Eksikliği

Birçok üretici, modern tarım teknikleri ve teknoloji kullanımında yetersiz kalmakla birlikte çiftçilerin çoğu, hastalık yönetimi, gübreleme ve sulama gibi temel konularda yeterli bilgiye sahip değildir. Modern tarım ekipmanlarının yüksek maliyeti nedeniyle küçük ölçekli üreticiler bu ekipmanlara erişememektedir.

3.7. İklim Değişikliği ve Kuraklık

Küresel iklim değişikliği, tarım sektörünü doğrudan etkilemektedir. Kuraklık, sulama imkanlarını sınırlamakta ve verimi düşürmektedir. Türkiye'nin birçok bölgesinde yer altı su seviyelerinde ciddi azalma görülmektedir.

3.8. Hastalıklar ve Zararlılar

Patates üretiminde en büyük sorunlardan biri hastalıklar ve zararlılardır. Patates yumrularının yüksek su içeriği (%70-80), birçok patojenin gelişimi için elverişli bir ortam oluşturmaktadır. Bu durum, özellikle yumuşak çürüklük ve kuru çürüklük gibi hastalıkların yayılmasına katkıda bulunur. Örneğin, *Fusarium* kuru çürüklüğü üzerine yapılan bir çalışmada, yüksek su içeriğine sahip taze hasat edilmiş patates yumrularının, hasat ve depolama sırasında daha savunmasız olduğu belirtilmiştir (Pavlou ve ark., 2021). Ayrıca, patatesin vejetatif olarak yumrularla çoğaltılması, onu generatif yollarla çoğaltılan kültür bitkilerine kıyasla bitki patojenlerine karşı daha hassas hâle getirmektedir. Vejetatif çoğaltma, patatesin genetik çeşitliliğini azaltır ve bu durum, tüm bitkilerin belirli bir hastalığa karşı aynı derecede savunmasız olmasına neden olabilir. Bu, özellikle geç yanıklık gibi yaygın hastalıkların hızla yayılmasına ve büyük ürün kayıplarına yol açabilmektedir (Savary ve ark., 2006).

4. PATATES ÜRETİMİNDE ZARAR YAPAN VE EKONOMİK ÖNEME SAHİP HASTALIK, ZARARLI VE YABANCI OTLAR

Tarımsal üretimde ekonomik kayba neden olan tüm hastalık ve zararlı grupları patates açısından yüksek öneme sahiptirler (Tablo 1). Patateste zarar yapan patojenler, virüsler, zararlılar ve yabancı otlardan kaynaklanan gerçek kayıplara ilişkin tahminler dünya genelinde sırasıyla %14, %7, %11 ve %8'dir. Patates üretiminde bitki koruma uygulamalarının yapılmaması durumunda elde edilecek ürünün neredeyse %75'i hastalık, zararlı ve yabancı otlar tarafından kaybedileceği belirtilmiştir. Bununla beraber mevcut ürün kayıpları Kuzeybatı Avrupa'da %24 civarındayken bu kayıplar Orta Afrika'da %50'lere kadar çıkmaktadır (Oerke, 2006). Bu durum tarımsal mücadele faaliyetlerinin önemini ve ayrıca yapılan uygulama yoğunluklarında ve/veya yapılan uygulamalarda elde edilen sonuçlarda farklılıklar olduğunu göstermektedir. Küresel ölçekte patateste ekonomik öneme sahip en önemli etmenler arasında *Phytophthora infestans, Alternaria* spp., *Ralstonia solanacearum, Pectobacterium* spp., *Dickeya* türleri, potato leafroll luteovirus, potato potyvirus Y, patates kist nematodları, patates böceği, patates güvesi sayılabilir (Chakrabarti vd., 2022).

Tablo 1. Önemli bazı ürünlerde küresel ölçekte hastalık, zararlı ve yabancı otlardan kaynaklanan ürün kayıpları (%)

Ürün	Zararlılar		Patojenler		Virüsler		Yabancı otlar		Toplam	
	P*	G	P	G	P	G	P	G	P	G
Buğday	8,7	7,9	15,6	10,2	2,5	2,4	23,0	7,7	49,8	28,2
Çeltik	24,7	15,1	13,5	10,8	1,7	1,4	37,1	10,2	77,0	37,4
Mısır	25,9	9,6	9,4	8,5	2,9	2,7	40,3	10,5	68,5	31,2
Patates	15,3	10,9	21,2	14,5	8,1	6,6	30,2	8,3	74,9	40,3
Soya fasülyesi	10,7	8,8	11,0	8,9	1,4	1,2	37,0	7,5	60,0	26,3
Pamuk	36,8	12,3	8,5	7,2	0,8	0,7	35,9	8,6	82,0	28,8

* P: Potansiyel kayıp, G: Gerçek kayıp

Türkiye'de tarımsal üretimde zarar yapan ve mücadele yapılması gerekliliği öngörülen hastalık, zararlı ve yabancı ot sayısı 2024 yılı itibariyle toplam 668'dir. Patateste ise altı tanesi ana hastalık ve zararlı olmak üzere 50'nin üzerinde patates üretiminde zarar yapan hastalık, zararlı ve yabancı ot türü bulunmaktadır (Tablo 2).

Tablo 2. Türkiye'de patates üretiminde zarar yapan ve ekonomik öneme sahip hastalık, zararlı ve yabancı ot türleri

Ana Zararlı ve Hastalıklar
Zararlılar
Patates böceği (*Leptinotarsa decemlineata* Say)
Patates güvesi (*Phthorimaea operculella* (Zeller))
Patates kist nematodları (*Globodera rostochiensis* Wollenweber, *G. pallida* Stone)
Kök ur nematodları (*Meloidogyne spp*. Goeldi)
Hastalıklar
Patates mildiyösü (*Phytophthora infestans* (Mont.) de Bary)
Patates siğil hastalığı (*Synchytrium endobioticum* (Schilb.) Percival)
Diğer Zararlı, Hastalık ve Yabancı Otlar
Zararlılar
Bozkurt (*Agrotis segetum* Schff., *A.ipsilon* Hufn.)
Telkurdu (*Agriotes spp*.)
Manas (Kadı lokması) (*Polyphylla turkmenoglui* Petr., *P.fullo* L.)
Yaprakbitleri, Patates yaprakbiti (*Aulacorthum solani*)
Patates yaprakbiti (*Macrosiphum euphorbiae*)
Patates yaprakbiti (*Aphis nasturtii*)
Şeftali yaprakbiti (*Myzus persicae*)
Pamuk yaprakbiti (*Aphis gossypii*)
Yaprak pireleri (*Empoasca fabae* Harris, *Empoasca decipiens* Paoli, *Asymmetrasca decedens* Paoli) *Hyalesthes obsoletus* Signoret
Patates çürüklük nematodu (*Ditylenchus destructor* Thorne)
Soğan-sak nematodu (*Ditylenchus dipsaci* Kühn)
Hastalıklar
Fungal Hastalıklar
Erken yaprak yanıklığı *(Alternaria solani* Sorauer *)*
Tozlu uyuz (*Spongospora subterranea* (Wallr.) Lagerh. f.sp. *subterranea* Toml.)
Solgunluk (*Fusarium* spp, *Verticillium* spp., *Colletotrichum coccodes* (Wallr.) Hughes)
Kuru çürüklük (*Fusarium* spp.)
Gümüşi leke (*Helminthosporium solani* Dur and Mont.)
Kökboğazı nekrozu ve siyah siğil (*Rhizoctonia solani* Kühn)
Bakteriyel Hastalıklar
Patateste bakteriyel yumuşak çürüklük ve karabacak (*Pectobacterium carotovorum* (Jones) Waldee emend. Portier ve ark., *Pectobacterium atrosepticum* (van Hall) Gardan ve ark., *Pectobacterium wasabiae* (Goto and Matsumoto) Gardan ve ark., *Pectobacterium brasiliense* Portier ve ark., *Pectobacterium parmentieri* Khayi ve ark., *Dickeya solani* van der Wolf ve ark.)

Patateste adi uyuz (*Streptomyces scabies* (Thaxter) Lambert and Loria, *Streptomyces turgidiscabies* Miyajima ve ark., *Streptomyces reticuliscabiei* Bouchek-Mechiche ve ark.)
Patateste bakteriyel solgunluk ve kahverengi çürüklük (*Ralstonia solanacearum*(Smith) Yabuuchi ve ark.)
Patates halka çürüklüğü (*Clavibacter sepedonicus* (Spieckermann & Kotthoff) Li ve ark.)
Patateste stolbur hastalığı (*Candidatus Phytoplasma solani*)

Tablo 2. Türkiye'de patates üretiminde zarar yapan ve ekonomik öneme sahip hastalık, zararlı ve yabancı ot türleri (Devam)

Virüs ve Viroid Hastalıkları
Patates yaprak kıvrılma virüsü (*Potato leafroll virus*, PLRV)
Patates Y virüsü (*Potato virus Y*, PVY)
Patates X virüsü (*Potato virus X*, PVX)
Patates A virüsü (*Potato virus A*, PVA)
Patates M virüsü *(Potato virus* M, PVM)
Patates S virüsü *(Potato virus* S, PVS)
Patates iğ yumru viroidi (*Potato spindle tuber viroid*, PSTVd)
Yabancı Otlar
Sirken (*Chenopodium album* L. (Chenopodiaceae))
Yabani Hardal (*Sinapis arvensis* L. (Brassicaceae))
Boynuzlu yoğurt otu (*Galium tricornutum* Dandy (Rubiaceae))
Tarla sarmaşığı (*Convolvulus arvensis* L. (Convolvulaceae))
Semizotu (*Portulaca oleracea* L. (Portulacaceae))
Tarla atkuyruğu (*Equisetum arvense* L (Equisetaceae.))
Kırmızı köklü tilki kuyruğu (*Amaranthus retroflexus* L. (Amaranthaceae))
Tilki kuyruğu (*Alopecurus myosuroides* Huds. (Poaceae))
Darıcan (*Echinochloa crus-galli* (L.) P.B. (Poaceae)
Köpek dişi ayrığı (*Cynodon dactylon* (L.) Pers. (Poaceae))
Küsküt (*Cuscuta campestris* L. (Convolvulaceae))

4.1. Bakteriyel hastalıklar

Doğada yüzbinlerce farklı bakteri türü bulunmasına rağmen bunlardan çok az bir kısmı patates için patojen durumundadır. Bakteriyel hastalıklar, özellikle tropikal ve subtropikal bölgelerde ve dünyanın bazı ılık ılıman bölgelerinde patates üretiminin en önemli biyotik kısıtlamalarından biri durumundadır (Charkowski ve ark., 2020). Patateste zarar yapan hastalık etmenleri arasında bakteriyel etmenler mücadelesi en zor olanları arasındadır. Bu durumun nedenleri arasında ilki bakterilerin uygun koşullar devam ettiği sürece hızla çoğalma potansiyeline sahip olması ve bunun sonucu olarak nispeten kısa bir süre içinde hastalık baskısının oluşmasıdır. İkincisi, bakteriyel etmenlerin bulaşıcılık seviyelerinin yüksek olması ve böylece hızlıca yayılma potansiyeline sahip olmalarıdır. Üçüncüsü, bazı bakteriyel etmenlerin hastalık gelişimlerinin erken aşamalarında latent halde olabilmeleri ve bunun sonucu olarak enfeksiyonun gözden kaçabilmesidir. Dördüncüsü ise bakteriyel hastalıkların mücadelesinin son derece zor olmasıdır. Bu durumun sonucu olarak bakteriyel hastalıkların görüldüğü alanlarda mücadelelerinde ciddi zorluklar yaşanmakta, karantina ve diğer önlemlerle yayılmalarını sınırlamak için önemli çaba sarf edilmektedir (Wale ve ark., 2008). Genel olarak, bakteriyel etmenlerin mücadelesinde kimyasal mücadele yok denecek ölçüde kısıtlı olup pestisitlerin kullanımı tohumluk yumrularının dezenfekte etmek için kullanımları ile sınırlıdır. Bazı çeşitler tolerans ve çeşitli düzeylerde dayanıklılık gösterse de, bakteriyel hastalıklara karşı dayanıklılık genellikle mevcut değildir (van der Wolf ve De Boer, 2007).

Patates üretiminde önemli ürün kayıplarına neden olan bakteriyel hastalık etmenleri arasında en önemlileri; karabacak ve yumuşak çürüklük hastalığı (*Dickeya* spp. ve *Pectobacterium* spp.), bakteriyel halka çürüklüğü hastalığı (*Clavibacter michiganensis* subsp. *sepedonicus*), kahverengi çürüklük hastalığı (*Ralstonia solanacearum*), uyuz hastalığı (*Streptomyces* spp.), yer almaktadır. Dünya genelinde riskli olan *Clavibacter michiganensis* subsp. *sepedonicus*,

Ralstonia solanacearum ve *Streptomyces scabies* ise karantina listesinde yer almaktadır (Van der Wolf ve De Boer, 2007, Doolotkeldieva ve ark., 2016, Baştaş, 2023).

4.2 Fungal hastalıklar

Patateste zarar yapan fungal organizmaların çeşitliliği son derece geniştir (Wale ve ark., 2008). Patateste zararlı 33 farklı fungal etmen bulunmakta olup bunlardan sekiz tanesi hava yoluyla bulaşırken 25 tür toprak kökenlidir. Bu etmenlerden *Puccinia piettieriana, Phoma andigena, Thecaphora solani* ve *Septoria lycopersici* var. *malagutii* A1, *Synchytrium endobioticum* ise A2 karantina listelerinde yer alan organizmalardır (EPPO, 2004). Karantina listesinde A1'de yer alan etmenler patatesin ana vatanı Güney Amerika ile sınırlıyken özellikle toprak kökenli olan fungal etmenlerin birçoğu dünyada patates üretimi yapılan alanlara yayılmış durumdadırlar (Termorshuizen, 2007). Fungal hastalık etmenlerinden bazıları yaprakta bazıları ise yumruda zarar yaparken birçoğu hem yaprak hem de yumruda zarar oluşturmaktadır (Rich, 2013).

Dünya çapında başlıca patates hastalıkları arasında mildiyö (*Phytophthora infestans*), erken yaprak yanıklığı (*Alternaria solani*), patates siğil hastalığı (*Synchytrium endobioticum*) ve tozlu uyuz (*Spongospora subterranea*) yer almaktadır. *Phytophthora infestans* patates üretimindeki en önemli biyotik kısıtlamaların başında gelmektedir. Yapraklarda açık ila koyu kahverengi lekeler, saplarda kahverengi lekeler ve yumrularda kırmızımsı kahverengi renkli hafif çöküntüler şeklinde görülebilmektedir. Hastalığın gelişmesi için yüksek nem ve ılıman sıcaklıklar gerekli olup uygun koşullar altında hastalık birkaç gün içinde bir tarlayı tamamen enfekte edebilmektedir. Patates yetiştirilen çoğu ülkede görülen erken yaprak yanıklığı etmeni yapraklarda tipik olarak eş merkezli halkalar şeklinde koyu kahverengi veya siyah lekeler oluşturmaktadır. Uygun koşullar altında özellikle hassas çeşitlerde önemli verim kayıplarına neden olan etmene karşı fungusit direnç gelişimi tespit edilmiş olması mücadelesini de zorlaştırmaktadır. Kökler hariç patatesin tüm meristematik dokularında gelişebilen ve yumruda karnabahar benzeri tipik belirteler oluşturan patates siğil hastalığı önemli bir karantina etmeni olmasına rağmen tüm dünyada patates yetiştirilen önemi alanların çoğuna yayılmış durumdadır. Konukçusu olmadan toprakta 40 yıla kadar canlılığını koruyabilen etmen patates üretiminde ciddi sorunların başında gelmektedir. Tozlu uyuz etmeni *Spongospora subterranea* dünya genelinde hem tohumluk hem de yemeklik patates üretiminde yumruda meydana getirdiği zarar sonucunda önemli ölçüde kalite ve verim düşüşlerine neden olmaktadır. Etmen aynı zamanda potato mop-top virus (PMTV)'nün vektörü durumundadır. Özellikle serin ve nemli koşullarda gelişen ve mücadelesi zor olan hastalık bulaşık yumrularla ve toprak hareketiyle yayılmaktadır (Adolf ve ark., 2020; Rich, 2013; Termorshuizen, 2007; Wale ve ark., 2008).

4.3 Virüs, Viroid ve Fitoplasmalar

Virüslerin tohumla taşınabilmeleri ve neden oldukları verim kayıplarının son derece yüksek olması nedeniyle patateste zarar yapan önemli etmenler arasındadır (Ross, 1986). Mücadele yöntemlerine yanıt vermemeleri ekonomik önemlerini daha da arttırmaktadır (Kolychikhina ve ark., 2021). Patateste zarar yapma potansiyeline sahip 50'den fazla virüs bulunmakla beraber *Potato leaf roll virus* (PLRV), *Potato spindle tuber viroid* (PSTVd), *Potato virus A* (PVA), *Potato virus X* (PVX), *Potato virus Y* (PVY), *Potato yellow vein virus* (PYVV), *Potato mop-top virus* (PMTV), *Tobacco rattle virus* (TRV) ve Tomato spotted wilt virus (TSWV) patates üretimi açısından büyük önem araz etmektedir. Diğer türlerin yayılımları ve önemleri son derece sınırlıdır (Wale ve ark., 2008). Birçok virüs hastalığının taşınmasında ve yayılmasında

vektörler önemli pay sahibidirler. Patateste viral etmenlerin zararı sonucunda bitkinin büyüme süreçlerinde bodurlaşma ve cücelik, yapraklarda mozaik lekeler, yaprak buruşması, damar nekrozu, büzülme, kloroz, yumrularda nekrotik halkalar, iç damar ölümü, çizgi şeklinde belirtiler meydana gelirken verim ve ürün kalitesinde de önemli düşüşler meydana gelmektedir (Kreuze ve ark., 2020, Valkonen, 2007).

4.4. Nematodlar

Birçok farklı ekosistemde canlılıklarını sürdüren ve hayvanlar aleminde tür sayısı açısından üçüncü, yoğunluk açısından ise birinci sırada gelen nematodlar içerisinde bitki paraziti nematodlar küçük bir kısmı oluşturmalarına karşın tarımsal üretimde önemli ölçüde kayıplara neden olmaktadırlar. Bitki paraziti nematodlar, patates yetiştirilen birçok alanda patates verimini ve kalitesini kısıtlayan önemli faktörlerden biri durumundadır (Lima ve ark., 2018; Niere ve Karuri, 2018). Patateste zarar yapan en önemli türler patates kist nematodları (*Globodera rostochiensis, G. pallida*) ile kök-ur nematodları (*Meloidogyne* spp.)'dır. Soğan sak nematodu (*Ditylenchus dipsaci*) ve patates çürüklük nematodu (*Ditylenchus destructor*) zararı tohumluk kalitesindeki artışa paralel olarak son yıllarda azalmıştır. Patateste verim üzerine mücadele yapılmaması durumunda %100'lere varan düzeyde zararla karşılaşılabilen bitki paraziti nematodlar aynı zamanda patateste kalite açısından da zarar oluşturmaktadırlar. Doğrudan yaptıkları zararın yanı sıra toprak kökenli etmenlere giriş kapısı oluşturmaları nedeniyle sekonder zarara da neden olmaktadırlar (Ravichandra, 2014). Meydana getirdikleri zarar genellikle popülasyon büyüklüğü ile ilişkili olmakla beraber popülasyon hızlı şekilde arttığı için tespit edildiği alanlarda kesinlikle mücadele yapılması gerekmektedir.

4.5. Zararlılar

Patates zararlıları çeşitlilik arz etmekle birlikte, zararlıların çoğu böceklerden oluşurken, diğer eklem bacaklı grupları da patateste zarar oluşturmaktadırlar. Patates zararlıları sıklıkla hareketlidirler ve büyük mesafelere ulaşabilme veya taşınabilme kabiliyetine sahiptirler. Uygun çevresel koşulların mevcut olduğu yerlerde hızla çoğalma yetenekleri de göz önüne alındığında meydana getirdikleri zarar mücadele yapılmaması durumunda ciddi seviyelere ulaşabilmektedir. Diğer patates patojen gruplarına kıyasla büyüklükleri nedeniyle, zararlılar nispeten kolay tanımlanırlar ve popülasyon yoğunluklarının izlenmesi genellikle mücadele programlarının bir parçasıdır. Birçok böcek zararlısı toprak üstü gövde veya toprak altı gövde dokusunda zarar yaparken yumruda zarar yapan tür sayısı göreceli olarak daha azdır. Patates böceği (*Leptinotarsa decemlineata*) bitki üst aksamında zarar yapan en bilinen ve zarar potansiyel, en yüksek olan zararlıların başında gelirken patates güvesi (*Phthorimaea operculella*) ve tel kurdu (*Agriotes* spp.) yumruda zarar yapan en önemli zararlılar arasında yer almaktadır. Başta yaprak bitleri olmak üzere bazı zararlılar aynı zamanda virüs vektörü durumundadırlar. Bu durumda, virüs vektörü zararlıların sayısı virüs taşıyıp taşımadıklarından daha az önemlidir. Patateste zarar yapan böceklerin tür ve biyolojilerinin çeşitlilik mücadelenin planlanmasını da zorlaştırmaktadır. Birçok böcek yaşam döngüsünde çeşitli aşamalardan geçer ve patatesler her zaman tüm aşamalar tarafından zarara uğramaz. Bu nedenle yaşam döngüsünün anlaşılması, kontrol önlemlerinin etkili olmasını sağlamak için çok önemlidir (Kroschel ve ark., 2020; Radcliffe ve Lagnaoui, 2007; Wale ve ark., 2008).

5. TÜRKİYEDE PATATES YETİŞTİRİCİLİĞİNDE KULLANILAN RUHSATLI PESTİSİTLER

Türkiye'de Kasım 2024 itibariyle patateste sorun olan hastalık, zararlı ve yabancı otlara yönelik olarak 94 farklı aktif ruhsatlı olup bunlardan bir tanesi biyolojik olmak üzere 46 tanesi fungusit olarak ruhsatlı iken 21 tanesi herbisit, iki tanesi desikant+herbisit, bir tanesi desikant, 15 tanesi insektisit, bir tanesi biyolojik olmak üzere beş tanesi nematisit, dört tanesi bitki gelişim düzenleyicisi olarak ruhsatlıdır. Herbisitler 38 farklı yabancı ot için ruhsatlıyken, insektisitler beş, fungusitler üç ve nematisitler ise iki farklı etmen için ruhsatlıdırlar. Bitki koruma ürünleri açısından değerlendirdiğimizde ise patateste ruhsatlı olan toplam148 bitki koruma ürününden 73 tanesi fungusit, 42 tanesi insektisit, 28 tanesi herbisit ve beş tanesi nematisit olarak ruhsatlıdır (Tablo 3) (Anonim, 2024).

Türkiye'de son 15 yılda zararlı olan hastalık, zararlı ve yabancı otlarla mücadelede kullanılan toplam bitki koruma ürünü miktarları ve bunun ürün tiplerine göre ayrılmış hali Tablo 4'de verilmiştir. Kullanılan toplam bitki koruma ürünü miktarı 2008 yılında toplam 38.836 ton iken 2023 yılında kullanılan toplam BKÜ miktarı %27,3'lük artışla 57.776 ton olarak gerçekleşmiştir. Yıllara göre değişimine baktığımızda kullanılan toplam BKÜ miktarının 2015 yılına kadar 40 bin bandının altında kaldığını ama 2016 yılı itibariyle sürekli 50 bin tonun üzerinde kullanıldığını ve en yüksek kullanım miktarına 2018 yılında 60.020 ton ile ulaşıldığı görülmektedir. Kullanılan BKÜ tipleri açısından değerlendirildiğinde ise 15 yıl açısından da en fazla kullanılan BKÜ grubu fungusitler olmuştur. Kullanılan toplam BKÜ miktarını 15 yıl için değerlendirdiğimizde %39,9'unu fungusitler oluşturmaktadır. Fungusitler sırasıyla herbisitler ve insektisitler izlerken son 15 yıl içerisinde beş yıl hariç herbisitler insektisitlerden daha fazla kullanılmıştır.

Son yıllarda ise herbisit kullanımıyla insektisit kullanımı arasındaki farkın arttığı ve herbisitlerin insektisitlere oranla yaklaşık %20 daha fazla kullanılmaya başlandığı görülmektedir. Rodentisit ve mollussisit kullanım miktarı ise yıllara göre değişmekle beraber düzenli bir artış veya azalış söz konusu değildir. Akarisitler açısından baktığımızda ise 2023 yılında 2008 yılına oranla akarisit kullanımı %321 artmış olmakla beraber son yıllarda önemli bir artış görülmemektedir.

Tablo 4. Türkiye'de Bitki Koruma Ürünleri Kullanım Miktarları (2008-2023)

Yıllar	Toplam[1]	İnsektisit[1]	Fungisit[1]	Herbisit[1]	Akarisit[1]	Rodentisit ve Mollussisit[1]	Diğerleri[1,2]
2008	38.836	9.251	16.707	6.177	737	351	5.613
2009	37.651	9.914	17.863	5.961	1.533	78	2.302
2010	38.555	7.176	17.396	7.452	1.040	147	5.344
2011	39.534	6.120	17.546	7.407	1.062	421	6.978
2012	42.611	7.264	18.124	7.351	859	247	8.766
2013	39.440	7.741	16.248	7.336	858	129	7.128
2014	39.723	7.586	16.674	7.794	1.513	149	6.007
2015	39.026	8.117	15.984	7.825	1.576	197	5.327
2016	50.054	10.425	20.485	10.025	2.025	259	6.835
2017	54.098	11.436	22.006	11.759	2.452	236	6.209
2018	60.020	13.583	23.047	14.794	2.486	309	5.801
2019	51.297	11.609	19.698	12.644	2.124	264	4.958
2020	53.672	12.347	20.600	13.250	2.200	280	4.995
2021	52.965	11.071	19.098	13.320	2.342	283	6.851
2022	55.374	12.205	19.446	14.553	2.462	298	6.410
2023	57.766	12.326	19.614	15.509	3.104	297	6.916

1 Ton

[2] Diğerleri: Bitki Aktivatörü+Bitki Gelişim Düzenleyici+Böcek Cezbedici+Fumigant+Nematisit

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Fungisit	Mildiyö (*Phytophthora infestans*)	%14 Metalik bakıra eşdeğer bakır hidroksit + %14 Metalik bakıra eşdeğer bakır oksiklorid	250 g / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%15 Metalik bakıra eşdeğer bakır hidroksit + %15 Metalik bakıra eşdeğer bakır oksiklorid + %6 Valiphenal	250 g / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%20 Metalik Bakıra Eşdeğer Bordo Bulamacı + %4 Cymoxanil	300 g/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%25 Mandipropamid + %18 Cymoxanil	60g/da	7 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	%26,7 Boscalid + %6,7 Pyraclostrobin	100 g/da	3 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%30 Cymoxanil + %22,5 Famoxadone	40g/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%30 Fluazinam+ %20 Cymoxanil	50 g/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%40 Metalaxyl-m + %4 Acibenzolar-s-methyl	30 g/da	14 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	%40 Metalik bakıra eşdeğer bakır hidroksit	250 g / 100 L su 125 g/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%40 Metalik bakıra eşdeğer bakır oksiklorid + %6 Dimethomorp	300 gr/100 l su	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%40,6 Metalik Bakıra Eşdeğer Bakır Oksiklorid + %8,4 Iprovalicarb	175 g / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%45 Cymoxanil	55 g/da	3 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%45,6 Cymoxanil + %15 Trifloxystrobin	50 g/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%50 Captan	350 gr / 100 lt su	28 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%50 Cymoxanil	50 gr/da	3 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%50 Metalik bakıra eşdeğer bakır oksiklorid	300 gr / 100 lt su	14 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	%50 Metalik bakıra eşdeğer bakır oksiklorid	500 gr / 100 lt su	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	%57 Metiram + %4,8 Cymoxanil	200 g/100 lt su	28 gün
Fungisit	Kökboğazı nekrozu ve siyah siğil (*Rhizoctonia solani*.)	100 g/l Penflufen + 18 g/l Prothioconazole	20 ml/100 kg tohum	-
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	125 g/l Azoxystrobin + 125 g/l Difenoconazole	80 ml/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	160 g/l Cyazofamid	50 ml/da	7 gün

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Fungisit	Patates kök boğazı çürüklüğü Siyah siğil hastalığı (*Rhizoctonia solani*)	160 g/l Metalaxyl + 100 g/l Thiophanate-methyl + 25 g/l Fludioxonil	50 ml / 100 kg tohum	-
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*) Mildiyö (*Phytophthora infestans*)	190 g/l Metalik Bakıra eşdeğer bazik bakır sülfat + 35 g/l Cymoxanil	350 ml / da	14 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	200 g/l Azoxystrobin + 125 g/l Difenoconazole	60 ml / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	200 g/l Azoxystrobin + 80 g/l Cyproconazole	50 ml/da	7 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	200 g/l Tebuconazole + 120 g/l Azoxystrobin	100 ml/da	14 gün
Fungisit	Patates kök boğazı çürüklüğü Siyah siğil hastalığı (*Rhizoctonia solani*)	25 g/L Fludioxonil	80 ml/100 kg tohum	-
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	250 g/l Azoxystrobin	75 ml / da	14 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	250 g/l Difenoconazole + 250 g/l Mandipropamid	60 ml /da	3 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	250 g/l Pyraclostrobin	60 ml/da	3 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*) Mildiyö (*Phytophthora infestans*)	259 g/l Metalik bakıra eşdeğer bakır hidroksit + 49 g/l Metalaxyl	200 ml / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	266,6 g/l Metalik bakıra eşdeğer bazik bakır sülfat + 40 g/l Zoxamide	300 ml/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	300 g/l Ametoctradin + 225 g/l Dimethomorph	80 ml/da	1 Gün
Fungisit	Siyah siğil (*Rhizoctonia solani*)	300 g/l Fluxapyroxad	20 ml/100 kg tohum	
Fungisit	Mildiyö (*Phytophthora infestans*)	300 g/L Zoxamide+ 40 g/L Oxathiapiprolin	50 ml/da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	300 g/LPhosphorous Acid (mono ve di-potasyum tuzları) + 75 g/L Ametoctradin	320 ml/da	7 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	375 g/l Fluazinam + 150 g/l Azoxystrobin	50 ml/da	7 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	400 g/L Fluazinam+193,6 g/L Metalaxyl-M	50 ml/da	7 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	400 g/l Phosphorous Acid (mono ve di-potasyum tuzları)	400 ml/100 l su	-
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	400 g/l Tea tree oil + 200 g/l Difenoconazole	35 ml/da	14 gün

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Fungisit	Patates kök boğazı çürüklüğü Siyah siğil hastalığı (*Rhizoctonia solani*)	50 g/L Fludioxonil+ 40 g/L Sedaxane	35 ml/100 Kg tohum	-
Fungisit	Mildiyö (*Phytophthora infestans*)	500 g/l Fluazinam	50 ml/da	7 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	600 g/l Phosphorous Acid (mono ve di-potasyum tuzları)	300 ml/da	-
Fungisit	Mildiyö (*Phytophthora infestans*)	65,82 g/l Metalik bakıra eşdeğer bakır sülfat	150 ml / da	14 gün
Fungisit	Mildiyö (*Phytophthora infestans*)	722 g/l Propamocarb-hydrochloride	250 ml/da	3 gün
Fungisit	Erken yaprak yanıklığı (*Alternaria solani*)	75 g/l Fluxapyroxad + 50 g/l Difenoconazole	75 ml/da	7 gün
Biyolojik Fungisit	Siyah siğil (*Rhizoctonia solani*)	%1,34 Bacillus amyloliquefaciens (B. subtilis) strain QST 713 min.1x10 üzeri 9 cfu/ml	2000 ml/da Önerilen dozun yarısı dikim öncesinde, diğer yarısı boğaz doldurma döneminde olmak üzere iki dönemde uygulanır.	
Herbisit	Bozot (*Heliotropium europeum*)	400 g/l Dimethenamid-p + 50 g/l Clomazone	125 ml/da çıkış öncesi	-
Herbisit	Sirken (*Chenopodium album*) Yabani hardal (*Sinapis arvensis*) Kanarya otu = İmam kavuğu (*Senecio vulgaris*) Isırgan otu (*Urtica urens*)	%24 Flufenacet + %17,5 Metribuzin	150 g/da Çıkış öncesi	
Herbisit	Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Söğüt otu (*Polygonum persicae*) Şahtere = Hakiki şahtere (*Fumaria officinalis*) Hakiki papatya (*Matricaria chamomilla*)	%24 Flufenacet + %17,5 Metribuzin	175 g/da Çıkış öncesi	
Herbisit	Darıcan (*Echinochloa crus-galli*) Kısır yabani yulaf (*Avena sterilis=Avena ludoviciana*)	100 g/l Cycloxydim	100 ml/da + 100 ml/da Zillion Çıkış sonrası	
Herbisit	Darıcan (*Echinochloa crus-galli*) Yapışkan ot (*Setaria verticillata*) Kanyaş (*Sorghum halepense*)	100 g/l Propaquizafop	50 ml/da Yabancı otların kardeşlenme devresinde,Kanyaş 20-40 cm iken	28 gün
Herbisit	Darıcan (*Echinochloa crus-galli*) Yapışkan ot (*Setaria verticillata*) Darıcan (*Echinochloa crus-galli*) Benekli darıcan (*Echinocloa colonum*) Yapışkan ot (*Setaria verticillata*)	116,2 g/l Clethodim	80 ml/da Çıkış Sonrası	35 gün

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Herbisit	Sarmaşık çoban değneği (*Polygonum convolvulus*) Yabani hardal (*Sinapis arvensis*) Odunsu köpek üzümü (*Solanum dulcamara*) Bozot (*Heliotropium europeum*) Demir dikeni (*Tribulus terrestris*) Yavşan otu (*Veronica* sp.) Yabani hardal (*Sinapis arvensis*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Yer fesleğeni = Köpek lahanası (*Mercurialis annua*) PITRAK (*Xanthium macrocarpus*) Sarmaşık çoban değneği (*Polygonum convolvulus*) Sirken (*Chenopodium album*) Bozot (*Heliotropium europeum*) Demir dikeni (*Tribulus terrestris*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Odunsu köpek üzümü (*Solanum dulcamara*) PITRAK (*Xanthium macrocarpus*) Sarmaşık çoban değneği (*Polygonum convolvulus*) Sirken (*Chenopodium album*) Yabani hardal (*Sinapis arvensis*) Yavşan otu (*Veronica* sp.) Yer fesleğeni = Köpek lahanası (*Mercurialis annua*)	%70 Metribuzin	50-75 g/da	42 gün
Herbisit	Köpekdişi ayrığı (*Cynodon dactylon*) Darıcan (*Echinochloa crus-galli*)	125 g/l Fluazifop-p-butyl	200 ml/da Patates bitkilerinin 15-20 cm yabancı otların 3-5 yapraklı olduğu devrede	
Herbisit	Darıcan (*Echinochloa crus-galli*)	150 g/l Fluazifop-p-butyl	100 ml/da Darıcanlar 8-10 cm boyda iken	
Herbisit + Desikant		200 g/l Diquat	Hasat öncesi yaprak kurutucu 1.uygulama : Hasattan 4 hafta önce 200 ml/da 2.uygulama: 1. Uygulamadan 1 hafta sonra 300 ml/da	
Herbisit	Sirken (*Chenopodium album*)	200 g/l Flurochloridone	250 ml/da Ekimden hemen sonra (çıkış öncesi)	

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Herbisit		200 g/l Diquat dibromide	Hasat öncesi yaprak kurutucu 200 ml/da 1.uygulama: Hasattan 4 hafta önce 300 ml/da 2.uygulama: 1.uygulamadan 1 hafta sonra	14 gün
Herbisit	Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*)	200 g/l Flurochloridone	250 ml/da Ekimden hemen sonra (çıkış öncesi)	
Herbisit	Köpek üzümü (*Solanum nigrum*)	250 g/l Flurochloridone	200-250 ml/da Dikimden sonra en geç 5 gün içinde (hafif toprakta düşük,ağır toprakta yüksek doz uygulanır.)	
Herbisit	Horoz ibiği (*Amaranthus* spp.) Sirken (*Chenopodium* album) Şahtere = Hakiki şahtere (*Fumaria officinalis*) Ballıbaba (*Lamium amplexicaule*) ÇOBAN DEĞNEĞİ (*Polygonum* spp) Yabani hardal (*Sinapis arvensis*)	250 g/l Metribuzin	144 ml/da çıkış öncesi	
Herbisit	Sirken (*Chenopodium album*) Yabani hardal (*Sinapis arvensis*) Yer fesleğeni = Köpek lahanası (*Mercurialis annua*) Semizotu (*Portulaca oleracea*) Bambul otu (*Chrozophora tinctoria*) Köpek papatyası (*Anthemis* sp.)	350 g/l Metribuzin	100 ml/da	42 gün
Herbisit	Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Ballıbaba (*Lamium amplexicaule*) Şeytan elması (*Datura stramonium*) Horozibiği (*Amaranthus albus*)	350 g/l Metribuzin	140 ml/da	
Herbisit	İri sinirotu (*Plantago major*) Kıvırcık labada (*Rumex crispus*) Sirken (*Chenopodium album*) Yabani hardal (*Sinapis arvensis*) Domuz pıtrağı (*Xanthium strumarium*) Gri lekeli amarant (*Amaranthus lividus*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Sirken (*Chenopodium album*) Yabani hardal (*Sinapis arvensis*)	360 g/l Clomazone	200 ml/da Çıkış öncesi	

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Herbisit	Darıcan (*Echinochloa crus-galli*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Semizotu (*Portulaca oleracea*) Sirken (*Chenopodium album*) Yapışkan ot (*Setaria verticillata*)	400 g/l Dimethenamid-p + 50 g/l Clomazone	125 ml/da çıkış öncesi	-
Herbisit	Köpek üzümü (*Solanum nigrum*)	400 g/l Dimethenamid-p + 50 g/l Clomazone	150 ml/da çıkış öncesi	-
Herbisit	Sirken (*Chenopodium album*) Köpek üzümü (*Solanum nigrum*) Yabani hardal (*Sinapis arvensis*) Gri lekeli amarant (*Amaranthus lividus*) Darıcan (*Echinochloa crus-galli*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Semizotu (*Portulaca oleracea*) Çatalotu (*Digitaria sanguinalis*)	400 g/l Pendimethalin	330 ml/da Çıkış Öncesi	
Herbisit	Darıcan (*Echinochloa crus-galli*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Sirken (*Chenopodium album*) Tarla akçaçiçeği (*Thlaspi arvense*) Yabani hardal (*Sinapis arvensis*)	400 g/l Pendimethalin + 40 g/l Diflufenican	300 ml/da	
Herbisit	Darıcan (*Echinochloa crus-galli*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Sirken (*Chenopodium album*) Yapışkan ot (*Setaria verticillata*)	455 g/l Pendimethalin	300 ml/da Çıkış öncesi	
Herbisit + Desikant		60 g/l Carfentrazone-ethyl	1. uygulama hasattan 4 hafta önce 100 ml/da 2. uygulama 1. uygulamadan 1 hafta sonra 60 ml/da	
Herbisit	Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*) Sirken (*Chenopodium album*) Darıcan (*Echinochloa crus-galli*)	600 g/l Metobromuron	300 ml/da çıkış öncesi	
Herbisit	Sirken (*Chenopodium album*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*)	600 g/l Pethoxamid	200 ml/da (Çıkış öncesi)	

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
Herbisit	Anadolu şahteresi (*Fumaria kralikii*)	800 g/l Prosulfocarb	500 ml/da	
Herbisit	Ebegümeci (*Malva neglecta*) Köpek üzümü (*Solanum nigrum*) Kadın tırnağı = Kırmızı ayaklı karabuğday (*Polygonum persicaria*) Bozot (*Heliotropium europeum*) Semizotu (*Portulaca oleracea*) Kırmızı köklü tilkikuyruğu (*Amaranthus retroflexus*)	800 g/l Prosulfocarb + 80 g/l Metribuzin	500 ml/da (pre-em)	
Desikant		10,6 g/l Pyraflufen-ethyl	200 ml/da Hasat öncesi olgun yumru dönemi	14 gün
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	%70 Chlorantraniliprole	6 g/da	14 gün
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	%20 Acetamiprid	6 g/da larva, ergin	7 gün
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	%25 Spinetoram	24 g/da ergin	
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	%50 Phosmet	200 g /100 l su Larva-ergin	
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	%70 Imidacloprid	15 g /100 kg tohum larva ergin	
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	100 g/l Chlorantraniliprole + 50 g/l Lambda-cyhalothrin	30 ml/da (Larva)	
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	100 g/l Cypermethrin	40 ml/ da	
İnsektisit	Tütün beyazsineği (Bemisia *tabaci*)	100 g/l Cypermethrin	75 ml/da	
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	120 g/l Spinetoram	50 ml/da ergin	
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	120 g/l Spinetoram	50 ml/da Larva, ergin	
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	200 g/l Chlorantraniliprole	20 ml/da	
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	222 g/l Flubendiamide	30 ml/100 L. su	
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	25 g/l Deltamethrin	30 ml/da	

Tablo 3. BKÜ veri tabanına kayıtlı patateste ruhsatlı bitki koruma ürünleri (devam)

Grubu	Zararlı Organizma	Aktif Madde	Dozu	HAS*
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	480 g/l Spinosad	10 ml/ da	3 gün
İnsektisit	Sebzelerde bozkurt (*Agrotis* spp.)	50 g/l Lambda-cyhalothrin	40 ml / 100 l su	3 gün
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	50 g/l Lambda-cyhalothrin	40 ml / da larva ergin	3 gün
İnsektisit	Patates güvesi (*Phthorimaea operculella*)	60 g/l Gamma-cyhalothrin	20 ml/da ergin	7 Gün
İnsektisit	Patates böceği (*Leptinotarsa decemlineata*)	60 g/l Gamma-cyhalothrin	20 ml / da Larva, ergin	7 gün
İnsektisit	Telkurtları (*Agriotes* spp.)	600 g/l Imidacloprid	35 ml /100 kg tohum larva	
Nematisit	Patates kist nematodları (*Globodera* spp.)	900 g/l Fosthiazate	250 ml/da (Birinci uygulama ekim öncesi yapılır. İkinci uygulama ilk uygulamadan 45 gün sonra yapılmalıdır.)	49 gün
Nematisit	Kök-ur nematodları (*Meloidogyne* spp.)	900 g/l Fosthiazate	250 ml/da	
Nematisit	Kök-ur nematodları (*Meloidogyne* spp.)	1* 10 8 kob/ml (%1.5) Paecilomyces lilacinus	500 ml/ da	
Nematisit	Kök-ur nematodları (*Meloidogyne* spp.)	400 g/l Fluopyram	120 ml/da	
Nematisit	Kök-ur nematodları (*Meloidogyne* spp.)	50 g/l Abamectin	400 ml/da dozda 3 uygulama	
Nematisit	Patates kist nematodları (*Globodera* spp.)	50 g/l Abamectin	400 ml/da dozda 3 uygulama	
Nematisit	Patates kist nematodları (*Globodera* spp.)	18 g/l Abamectin	1 litre/da (3 uygulama 15 gün ara ile)	
Nematisit	Kök ur nematodları (*Meloidogyne* spp.)	18 g/l Abamectin	1 litre /da (3 uygulama 15 gün ara ile)	
BGD		%100 Spearmint Oil	45 ml/ 1 ton patates Hasat sonrası depolama sırasında filizlenme engelleyici	
BGD		1 g/tb Gibberellic Acid	100 lt suya 2 tablet Tohumluk olarak kullanılacak patatesler,dikiminden önce hazırlanan solüsyona dikimden önce daldırılarak muamele edilir ve dikilir. Böylece çimlenme hızlanır ve düzenli çıkış olur. Tüketim amaçlı bağ yaprağı hasadı yapılacak bağ alanlarında kullanılmaz.	
BGD		20 g/l Gibberellic acid	100lt su 30-60ml+20ml yayıcı-yapıştırıcı	
BGD		20 g/l Gibberellic acid	100 lt suya 25-50 ml	
BGD		843,2 g/l Portakal Yağı	100 ml/ 1 ton patates	

6. SONUÇ

Tarımsal faaliyetlerin başlangıcından bu yana insanlar ürünlerinde kayıplara neden olan hastalık, zararlı ve yabancı otlarla mücadele halindedir. Bu kapsamda 1900'lü yılların başından 1960'lara kadar kimyasal mücadelenin kullanım oranı her geçen gün artarak devam etmiştir.

Bu yılların devamında zararlı yönetimi, ekonomik zarar eşiği, entegre kontrol gibi kavramlar hayatımıza girmiş ve özellikle "Sessiz Bahar" isimli kitabın yayınlanmasından sonra başlayarak günümüze kadar artarak devam eden pestisitlerin olumsuz yönlerine yönelik bir farkındalık artışı olmuştur. Özellikle son yıllarda yapılan mevzuatsal değişiklikler sonucunda yoğun olarak kullanılan birçok pestisitin kullanımı gerek Avrupa'da gerekse de ülkemizde yasaklanmıştır. Hatta Avrupa Birliği, ilerleyen süreçte pestisit kullanımını tamamen kaldıracağını Green Deal kapsamında beyan etmiş durumdadır. Oluşan tüm bu olumsuz duruma rağmen hali hazırda tüm dünyada en çok başvurulan, üreticilerin en hızlı ve yüksek oranda sonuç aldıkları mücadele yönteminin kimyasal mücadele olduğu gerçeği değiştirmemektedir. Mevcut bitki koruma uygulamaları sonucunda hasatlık, zararlı ve yabancı otlardan kaynaklanan kayıplar küresel ölçekte %30-40 azaltılmakla beraber bu etkinin büyük bir kısmı kimyasal mücadele sayesinde oluşmaktadır.

Patates neredeyse tüm dünyada yetiştirilen, verim ve besleyicilik özellikleri son derece yüksek olan en önemli besin kaynaklarından biri durumundadır. Gerek vejetatif olarak yumruları ile çoğaltılması gerekse de patatesten elde edilen ürün olan yumruların toprak altında yer alması nedeniyle patates hastalık, zararlı ve yabancı otlardan en fazla kayıpların yaşandığı bitkilerin başında gelmektedir. Her ne kadar elimizde bitki bazında pestisit kullanımı ile ilgili veriler bulunmasa da ruhsatlı olan ürün sayıları göz önüne alındığında patatesin en fazla bitki koruma ürünü kullanılan bitkilerin başında geldiğini ve fungisit, herbisit ve insektisitlerin en çok kullanılan bitki koruma ürünleri olduğunu söyleyebiliriz.

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BIBLIOMETRIC ANALYSIS OF SCIENTIFIC PUBLICATIONS ON THE USE OF MENTHA AND LAVANDULA ESSENTIAL OILS AGAINST SOME STORAGE PESTS

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ABSTRACT

Stored product pests, which occur during the storage of agricultural products, are one of the most important agricultural pests because they seriously affect the quantity and quality of the product as a result of the damage they cause to the product. Storage pests, which can potentially be found in all warehouses, cause 10-30% damage to the world's annual cereal production. Although chemical pesticides are most commonly used to control storage pests, both the direct consumption of stored products and increasing concerns about pesticide use in recent years have led to the development of more environmentally friendly approaches. Therefore, interest in biological control methods based on natural components such as essential oils of plant origin has increased in recent years. In this study, the scientific literature on the use of essential oils from the genera *Mentha* and *Lavandula* against the main storage pests *Sitophilus*, *Tribolium* and *Rhyzopertha* species was systematically reviewed using Scopus databases and a bibliometric analysis of the results obtained was carried out using Biblioshiny in R Studio. Various metrics such as research trends, influential authors, journals, keyword patterns and country contributions were evaluated. A general evaluation of the results obtained shows that the studies have a history of 24 years and consist of 100 articles in 72 different sources. Nevertheless, an annual growth rate of 2.93% and a citation/publication ratio of 28.53 indicate that this topic is increasingly on the research agenda. Publications are particularly concentrated in countries such as Morocco, Italy and India, with an average of 5.32 co-authors and an international co-authorship rate of 33%, indicating that research in this area is largely collaborative. It is hoped that the findings will help researchers identify existing scientific gaps and identify opportunities for collaboration between scientists working in the field. In addition,

it is aimed to provide information that can contribute to the development of natural pesticide use for policy makers and the agricultural sector.

Keywords: storage product pests, mentha, lavandula, essential oil, bibliometric analysis

BAZI DEPO ZARARLILARINA KARŞI MENTHA VE LAVANDULA UÇUCU YAĞLARININ KULLANIMINA YÖNELİK BİLİMSEL YAYINLARIN BİBLİYOMETRİK ANALİZİ

ÖZET

Tarım ürünlerinin depolanması sırasında karşılaşılan depo zararlıları, ürün üzerinde yaptıkları zarar sonucunda ürün miktarı ve kalitesini ciddi şekilde etkilemeleri nedeniyle önemli tarımsal zararlıların başında gelmektedirler. Potansiyel olarak tüm depolarda bulunabilen depo zararlıları yıllık küresel tahıl üretimine %10-30 oranında zarar vermektedirler. Depo zararlılarına karşı çoğunlukla kimyasal pestisitler kullanılmakla beraber hem depolanmış ürünlerin doğrudan tüketilmesi hem de son yıllarda pestisit kullanımına ilişkin endişelerin artması, daha çevre dostu yaklaşımların geliştirilmesine yol açmıştır. Bu nedenle, bitkisel kaynaklı uçucu yağlar gibi doğal bileşenlere dayanan mücadele yöntemlerine olan ilgi son yıllarda artmıştır. Çalışma kapsamında başlıca depo zararlıları olan *Sitophilus, Tribolium* ve *Rhyzopertha* türlerine karşı *Mentha* ve *Lavandula* cinslerinden elde edilen uçucu yağların kullanımına dair bilimsel literatürü Scopus veri tabanları üzerinden sistematik bir şekilde incelenmiş ve elde edilen sonuçların bibliyometrik analizi R Studio'da Biblioshiny ile gerçekleştirilmiştir. Araştırma eğilimleri, etkili yazarlar, dergiler, anahtar kelime örüntüleri ve ülkesel katkılar gibi çeşitli metrikler bu kapsamda değerlendirilmiştir. Elde edilen sonuçlar genel olarak değerlendirildiğinde çalışmaların 24 yıllık bir geçmişi olduğu ve 72 farklı kaynakta yer alan 100 makaleden oluştuğu görülmektedir. Bununla beraber %2.93'lük yıllık büyüme oranı ve 28.53 atıf/yayın düzeyi, bu konunun araştırma gündeminde giderek daha fazla yer bulduğunu göstermektedir. Yayınlar özellikle Fas, İtalya ve Hindistan gibi ülkelerde yoğunlaşırken ortalama 5.32 ortak yazar ve %33 uluslararası ortak yazarlık oranı, bu alanda yürütülen çalışmaların büyük ölçüde iş birliğine dayalı olduğunu göstermektedir. Elde edilen bulguların, araştırmacılara mevcut bilimsel boşlukları görme ve bu alanda çalışan bilim insanları arasında iş birliği fırsatlarını belirleme açısından yol gösterici olacağı düşünülmektedir. Ayrıca, politika yapıcılar ve tarım sektörü için doğal pestisit kullanımının gelişimine katkı sağlayabilecek bilgiler sunulması hedeflenmektedir.

Anahtar kelimeler: depo zararlıları, mentha, lavandula, uçucu yağ, bibliyometrik analiz

1. GİRİŞ

Depolanmış tarım ürünlerinin korunması hem gıda güvenliği hem de ekonomik sürdürülebilirlik açısından küresel ölçekte büyük önem taşımaktadır. Ancak, depolama sürecinde özellikle böcek zararlılarından kaynaklanan kayıplar, ciddi ekonomik zararlara yol açmakta; ürün kalitesini düşürmekte ve dolaylı olarak tüketici sağlığını tehdit etmektedir (Stathas ve ark., 2023). En yaygın depo zararlıları arasında yer alan *Sitophilus oryzae* (pirinç biti), *Tribolium confusum* (kırma biti) ve *Rhyzopertha dominica* (ekin kambur biti) gibi türler, dünya genelinde tahıl depolarında yaygın olarak tespit edilmekte ve ciddi ekonomik zararlara yol açmaktadır (Wakil ve ark., 2023). Bu zararlılarla mücadelede uzun yıllardır yaygın olarak kullanılan sentetik pestisitler, başlangıçta etkili çözümler sunmuş olsa da zamanla çevresel kalıntı birikimi, pestisit direncinin gelişmesi, hedef dışı organizmaların zarar görmesi ve insan sağlığı üzerindeki toksik etkiler gibi çeşitli olumsuzlukları da beraberinde getirmiş ve bu durum kimyasal yöntemlerin sürdürülebilirliğini tartışmalı hale getirmiştir. Bu nedenle, daha güvenli, çevre dostu ve sürdürülebilir alternatif mücadele yöntemlerine olan ihtiyaç artmıştır (Basavakiran ve ark., 2025). Özellikle bitkisel kaynaklı uçucu yağlar, doğal biyopestisitler kapsamında sürdürülebilir tarım uygulamalarında umut vadeden alternatifler olarak öne çıkmaktadır (Pavela ve Benelli, 2016). Uçucu yağlar, bitkilerin ikincil metabolitleriyle oluşturdukları karmaşık kimyasal kompozisyonlar olup antimikrobiyal, antifungal, antifeedant, repellent ve toksik etki profilleri sergilemektedir (Singh ve ark., 2012; Said-Al Ahl ve ark., 2017). Bu etkiler özellikle *Lamiaceae* familyası üyelerinde; menthol, pulegone, carvone, linalool ve limonene gibi monoterpen bileşenlerde yoğunlaşarak, depo zararlıları üzerinde yüksek insektisidal potansiyele dönüşmektedir (Singh ve Pandey, 2018). *Mentha* (*M. piperita*, *M. pulegium*, *M. spicata*) ve *Lavandula* (*L. angustifolia*, *L. stoechas*) türlerinin sahip olduğu menthol, pulegone, carvone ve linalool gibi yüksek orandaki monoterpenoid bileşikler, bu yağların depo zararlıları üzerinde belirgin bir insektisidal potansiyele sahip olmasını sağlamaktadır. Bu bileşikler fumigant, temas toksisitesi ve yutma yoluyla böceklerin ölümüne, beslenme davranışlarının bozulmasına, yumurtlamanın engellenmesine, larva gelişiminin azalmasına ve repellent etkiye sebep olabilmektedir (Akşit, 2025; Alkan ve ark., 2024, Karabörklü ve Ayvaz, 2023; Nerio ve ark., 2010; Yazdani ve ark., 2013).

Son yıllarda bitkisel uçucu yağlara yönelik ilgi, yalnızca biyolojik etkinlik düzeyinde değil; aynı zamanda bunların kimyasal bileşimleri, etki mekanizmaları ve uygulama tekniklerine ilişkin çok boyutlu bilimsel çalışmalara evrilmiştir (Yu, 2025; Karabörklü ve Ayvaz, 2023). Bu bağlamda, *Sitophilus*, *Tribolium* ve *Rhyzopertha* türlerine karşı *Mentha* ve *Lavandula* cinslerinden elde edilen uçucu yağların kullanımına dair yapılan akademik çalışmaların artış gösterdiği gözlemlenmektedir. Söz konusu çalışmaların değerlendirilmesi hem bilimsel eğilimleri hem de gelecekteki araştırma alanlarını belirleme açısından önem arz etmektedir.

Bilimsel üretimin yönünü, etki düzeyini ve iş birliklerini analiz etmek amacıyla kullanılan bibliyometrik analiz, bu tür literatür birikimlerinin değerlendirilmesinde etkin bir araçtır. Bibliyometrik yöntemler, bir araştırma alanının zaman içerisindeki gelişimini, yayın sayıları, yazar ağları, anahtar kelime dağılımları, coğrafi katkılar gibi birçok değişken üzerinden ortaya koyabilmektedir (Aria ve Cuccurullo, 2017). Özellikle SCOPUS gibi geniş kapsama sahip veri tabanlarının kullanılması, analizlerin güvenilirliğini artırmaktadır.

Bu çalışmada, SCOPUS veri tabanında yer alan ve *Mentha* ile *Lavandula* türlerinden elde edilen uçucu yağların *Sitophilus oryzae*, *Tribolium confusum* ve *Rhyzopertha dominica* gibi temel depo zararlılarına karşı kullanımını konu edinen bilimsel yayınlar, bibliyometrik yöntemlerle analiz edilmiştir. Analizlerde R programına entegre edilen “bibliometrix” paketi kullanılarak

yıllara göre yayın sayıları, atıf düzeyleri, en üretken yazarlar, kurumlar ve ülkeler, tematik kümeler ve iş birlikleri değerlendirilmiştir.

2. MATERYAL VE METOT

Çalışma kapsamında SCOPUS veri tabanında yer alan dergilerde yayınlamış çalışmaların başlık, özet ve veya anahtar kelimelerinde ((“Sitophilus oryzae” OR "Tribolium confusum" OR "Rhyzopertha dominica ") AND (“Mentha longifolia” OR “Lavandula angustifolia” OR “Mentha piperita”) AND ("essential oil" OR "EOs")) girişine uygun olan çalışmalar 05.05.2025 tarihi itibariyle araştırılmıştır. Bu arama sonucunda 100 farklı dokümana ulaşılmıştır. Elde edilen bu sonuçlar daha sonra R programına aktarılmış ve verilere bibliyometrik analiz uygulanmıştır. Analizler için Aria ve Cuccurullo (2017) tarafından geliştirilen “bibiliometrix” isimli paket R programı kullanılmıştır.

3. BULGULAR

Çalışma kapsamında SCOPUS veri tabanından elde edilen çalışmaların analizi sonucunda elde edilen tanımlayıcı analiz sonucuna ait temel bilgiler Tablo 1’de verilmiştir. Bibliyometrik analiz kapsamında incelenen çalışmalara bakıldığında başlıca depo zararlıları olan *Sitophilus*, *Tribolium* ve *Rhyzopertha* türlerine karşı *Mentha* ve *Lavandula* cinslerinden elde edilen uçucu yağların kullanımına dair bilimsel literatürün 2001–2025 yılları arasındaki zaman dilimini kapsadığı ve konuya ilişkin bilimsel ilginin sürdürülebilir şekilde devam ettiğini göstermektedir. Analiz edilen toplam 100 makaleyi içeren belge, 72 farklı akademik dergiden oluşan kaynaktan elde edilmiştir. Bu çeşitlilik, konunun disiplinler arası nitelik taşıdığını ve entegre bir araştırma alanı haline geldiğini ortaya koymaktadır. Yıllık ortalama yayın artış oranının %2.93 olarak hesaplanması, araştırma konusunun özellikle son yıllarda ivme kazandığını ve çevre dostu biyopestisit çözümlerine olan akademik ilginin arttığını göstermektedir. Belgelerin ortalama yaşının 7.33 yıl olması ise bu alandaki yayınların güncelliğini koruduğunu ve hâlen aktif olarak yeni çalışmalarla desteklendiğini ortaya koymaktadır. Bu genel görünüm, *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus*, *Tribolium*, *Rhyzopertha* türlerinin mücadelesinde kullanımı üzerine yapılan araştırmaların hem güncel hem de giderek artan bir ilgiyle sürdüğünü göstermektedir. Bibliyometrik analiz kapsamında değerlendirilen 100 akademik çalışmada toplam 441 farklı yazar görev almış olup bu durum konuya olan uluslararası akademik ilgiyi ve disiplinler arası katılım düzeyini yansıtmaktadır. Analiz edilen belgeler arasında yalnızca bir çalışma tek yazarlı olarak yayımlanmış olması araştırma alanında iş birliğine dayalı üretimin baskın olduğunu ve yürütülen araştırmaların genellikle ekip çalışmasına dayandığını göstermektedir.

1. Tablo 1. Tanımlayıcı analiz: Koleksiyona ilişkin temel bilgiler

Veriler Hakkında Ana Bilgiler	
Zaman aralığı	2001:2025
Kaynaklar (Dergi, Kitap vb.)	72
Belge Sayısı	100
Yıllık Büyüme Oranı (%)	2,93
Belgelerin Ortalama Yaşı	7,33
Belge Başına Ortalama Atıf	28,53
Yazarlar	
Yazar	441
Tek Yazarlı Belgelere Ait Yazar	1
Yazar İşbirlikleri	
Tek Yazarlı Belge	1
Belge Başına Ortak Yazar	5,32
Uluslararası Ortak Yazarlıklar (%)	33
Belge Türleri	
Makale	100

Yıllara göre yayımlanan makalelerin dağılımı, araştırma konusunun zaman içerisinde nasıl bir gelişim gösterdiğine dair önemli ipuçları sunmaktadır. Şekil 1 incelendiğinde konuyla ilgili ilk makalenin 2001 yılında yayınlandığı, üretimin 2001–2003 yılları arasında her yıl yalnızca birer yayınla sınırlı kaldığı ve 2004–2006 döneminde ise tamamen durma noktasına geldiği görülmektedir. Ancak 2007 yılından itibaren yayın sayılarında yeniden artış gözlenmiş ve bu artış özellikle 2011 sonrası daha istikrarlı bir hâl almıştır. 2012 yılında ulaşılan 7 yayınlık üretim, konunun literatürde yeniden önem kazanmaya başladığını göstermektedir. Özellikle 2018 ve 2019 yıllarında sırasıyla 8 ve 9 yayınla zirveye ulaşılması, çalışmaya esas uçucu yağların depo zararlılarına karşı kullanımına yönelik araştırmalara olan ilginin belirgin şekilde arttığını ortaya koymaktadır. Bu durum, doğal pestisitlere olan yönelimin ve sürdürülebilir tarım uygulamalarına duyulan gereksinimin bilimsel çalışmalara da yansıdığı şeklinde de yorumlanabilir.

Yıllara göre yayımlanan makalelerin ortalama toplam atıf sayıları ve yıllık ortalama atıf düzeyleri, araştırma konusunun literatürdeki etkisini ve görünürlüğünü değerlendirme açısından önemli bir göstergedir. 2007 yılında yayımlanan tek bir makale, aldığı 264 atıf ile dönemsel olarak en yüksek etkiyi yaratmıştır (Şekil 1). Bu çalışmanın, alan açısından sıklıkla referans gösterilen ve muhtemelen metodolojik ya da uygulama açısından özgünlük taşıyan bir yayın olduğu değerlendirilebilir. 2001 ve 2002 yıllarında yayımlanan çalışmalar da sırasıyla 114 ve 87 toplam atıf ile yüksek etki düzeyine sahiptir. Bu durum, özellikle erken dönem literatürünün araştırma alanına yön veren temel çalışmaları içerdiğini göstermektedir. Bu yıllara ait makalelerin yıllık ortalama atıf sayılarının da sırasıyla 4.56 ve 3.62 olduğu dikkate alındığında, bu etkilerin sürdürülebilir olduğu görülmektedir. Buna karşın daha sonraki yıllarda yayımlanan bazı çalışmaların ortalama toplam atıf sayılarında bir düşüş gözlenmektedir. Örneğin 2008 yılına ait 3 çalışmanın ortalama toplam atıf sayısı 50.67, yıllık ortalama atıf düzeyi ise 2.82 ile sınırlı kalmıştır. Bu bulgu, yeni yayınların literatürde etki yaratması için

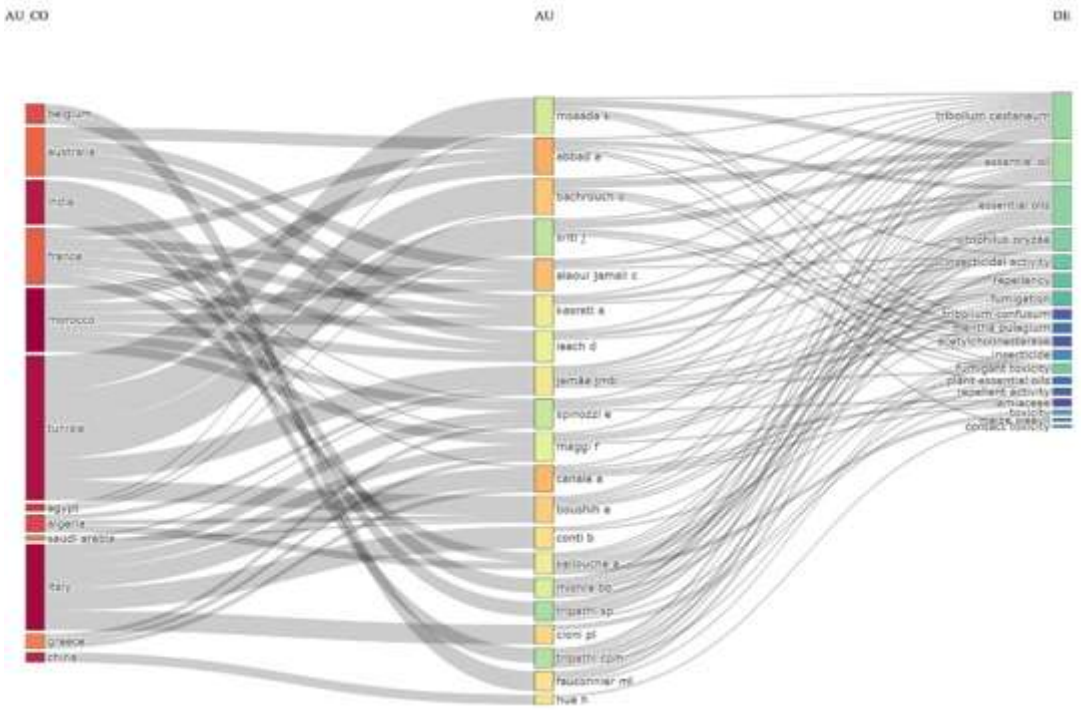
belirli bir zamana ihtiyaç duyduğunu ya da daha yeni çalışmaların henüz yeterince görünürlük kazanmadığını düşündürmektedir.



Şekil 1. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmaların ve makale başına ortalama atıf sayılarının yıllara göre değişimi

Yüksek katkı sağlayan ülkelerin, üretken yazarlar ve odaklanılan araştırma temaları ile olan ilişkisini gösteren ve Şekil 2'de verilen Sankey diyagramı, literatürdeki coğrafi-tematik kümelenmeyi açık biçimde gözler önüne sermektedir. Çalışmalarda yer alan ve en sık kullanılan yazar anahtar kelimeleri (DE) arasında *essential oil, Tribolium castaneum, Sitophilus oryzae,* fumigation, repellency, insecticidal activity gibi terimler ön plana çıkmaktadır. Bu anahtar kelimeler, bitkisel kökenli uçucu yağların özellikle bu iki önemli depo zararlısı üzerinde böcek öldürücü, fumigant ve repellent etkilerinin araştırıldığını göstermektedir. Diğer yandan, acetylcholinesterase ve chemical composition gibi biyokimyasal ve içerik temelli terimlerin de bulunması, çalışmaların sadece biyolojik etkiyle sınırlı kalmayıp, mekanizma düzeyinde analizler içerdiğini de ortaya koymaktadır. Ülke dağılımı incelendiğinde ise Fas, Tunus, Mısır, Hindistan, İran, Çin ve Türkiye gibi ülkelerin öne çıktığı görülmektedir. Fas kökenli araştırmacılar arasında Bachrouch O., Msaada K. ve Sriti J. öne çıkarken; bu yazarların çalışmaları çoğunlukla *Tribolium castaneum, Sitophilus oryzae,* essential oil, repellency gibi anahtar kavramlar etrafında şekillenmiştir. Bu da Fas merkezli araştırma gruplarının özellikle depo zararlıları ve uçucu yağ etkileşimlerine yönelik deneysel çalışmalara ağırlık verdiğini göstermektedir. Tunus'ta ise Abbad A., Alaoui Jamali C. ve Jemâa JMB gibi yazarların, fumigation, toxicity, chemical composition gibi anahtar terimlerle güçlü bağlantıları bulunmaktadır. Bu durum, Tunus'ta yürütülen çalışmaların yalnızca biyolojik aktiviteyle değil, aynı zamanda uçucu yağların kimyasal içeriği ve etki mekanizmalarıyla da ilgilendiğini göstermektedir. Benzer şekilde, Hindistan kökenli araştırmacılar olan Mishra BB., Tripathi SP. ve Tripathi CPM., özellikle repellent activity, contact toxicity, maize weevil ve plant essential oils anahtar kelimeleriyle güçlü biçimde ilişkilidir. Bu da Hindistan'daki çalışmalarda hem bitki bazlı pestisitlerin etkinliğinin hem de farklı zararlı türlerinin hedef alındığını göstermektedir.

Türkiye kökenli araştırmacıların sayıca diğer üretken ülkelere kıyasla daha sınırlı sayıda olmasına rağmen, çalışmalardaki tematik çeşitlilikleri ve katkı sundukları kavramsal alanlar dikkate değerdir. Türkiye menşeli yazarlar, özellikle essential oils, *Sitophilus oryzae*, fumigation, repellency, insecticidal activity, acetylcholinesterase gibi anahtar kavramlar etrafında yoğunlaşmıştır. Bu, Türkiye'deki çalışmaların hem pratik zararlı mücadelesi hem de biyokimyasal etki mekanizmaları düzeyinde yürütüldüğünü göstermektedir.

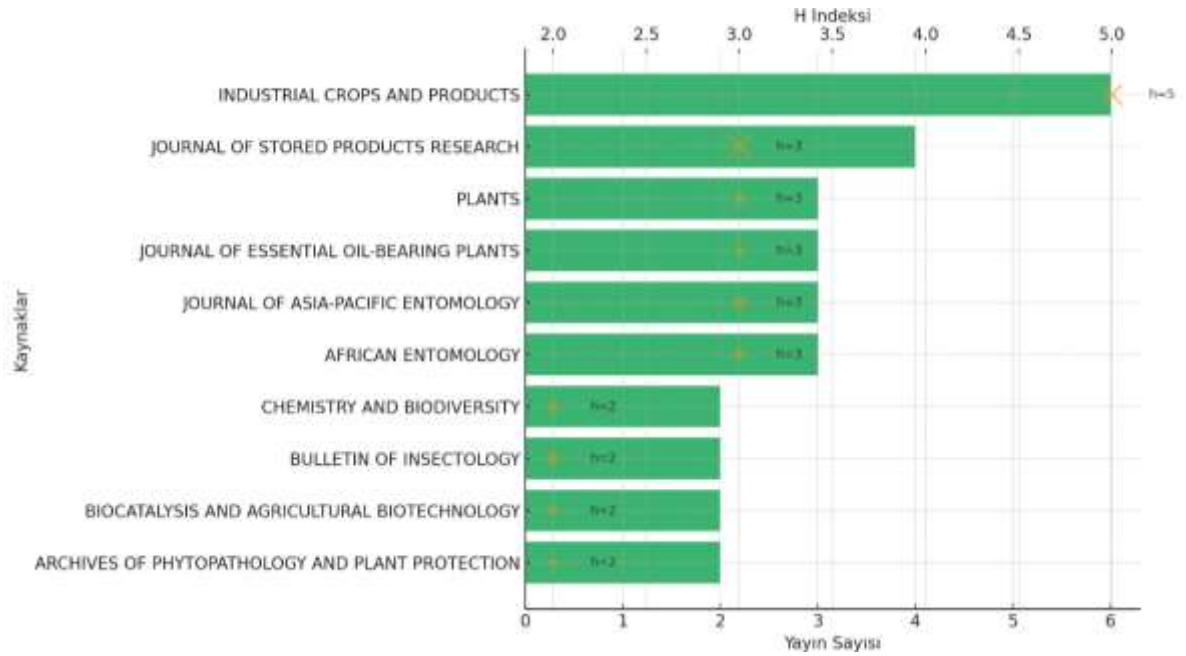


Şekil 2. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium* ve *Rhyzopertha* türleri üzerine etkisini konu alan çalışmalarda; katkı sağlayan ülkeler (AU_CO), araştırmacılar (AU) ve yazar anahtar kelimeleri (DE) arasındaki ilişkileri gösteren Sankey diyagramı

Yapılan bibliyometrik analiz, *Mentha* ve *Lavandula* türlerinden elde edilen uçucu yağların *Sitophilus, Tribolium* ve *Rhyzopertha* gibi depo zararlıları üzerindeki etkilerini inceleyen literatürde hem yayın hacmi hem de akademik etki açısından öne çıkan dergileri ortaya koymuştur (Şekil 3). Çalışmaların yayınlandıkları dergilere bakıldığında çalışmaya esas konulardaki makalelerin SCOPUS veri tabanında taranan 72 farklı dergide yayınladığı görülmektedir. Yayın sayısı bakımından ilk sırada yer alan Industrial Crops and Products dergisi, toplam 6 yayın ile en üretken kaynak konumundadır. Bu dergiyi sırasıyla Journal of Stored Products Research (4 yayın), African Entomology (3 yayın), Journal of Asia-Pacific Entomology (3 yayın) ve Journal of Essential Oil-Bearing Plants (3 yayın) takip etmektedir. Bu dergiler, bitki koruma, doğal pestisitler ve entomoloji gibi konulara odaklanan çalışmalara ev sahipliği yapmaktadır.

Etki düzeyleri incelendiğinde, Industrial Crops and Products dergisi aynı zamanda en yüksek H indeksi (h = 5) değerlerine sahiptir; bu da sadece yayın sayısı açısından değil, aynı zamanda yayınlarının aldığı atıf sayısı bakımından da güçlü bir etkiye sahip olduğunu göstermektedir. Journal of Stored Products Research ise her ne kadar h-indeksi 3 olarak gözükse de, toplam 426 atıf ile en fazla atıf alan dergi olmuştur. Bu bulgu, söz konusu dergide yayımlanan çalışmaların uzun süreli ve geniş çaplı bir etki yarattığını göstermektedir. Diğer üç dergi olan African Entomology, Journal of Asia-Pacific Entomology ve Journal of Essential Oil-Bearing Plants,

her biri 3'er yayınla katkı sağlamış olup, benzer şekilde h-indeksi 3 olarak kaydedilmiştir. Bu dergilerin görece daha dengeli ama etkili bir yayın profili sergilediği söylenebilir. Sonuç olarak, bu iki analiz birlikte değerlendirildiğinde özellikle *Industrial Crops and Products* ve *Journal of Stored Products Research*, araştırmaların görünürlüğünü artırmak açısından önemli yayın organları olarak değerlendirilebilir.

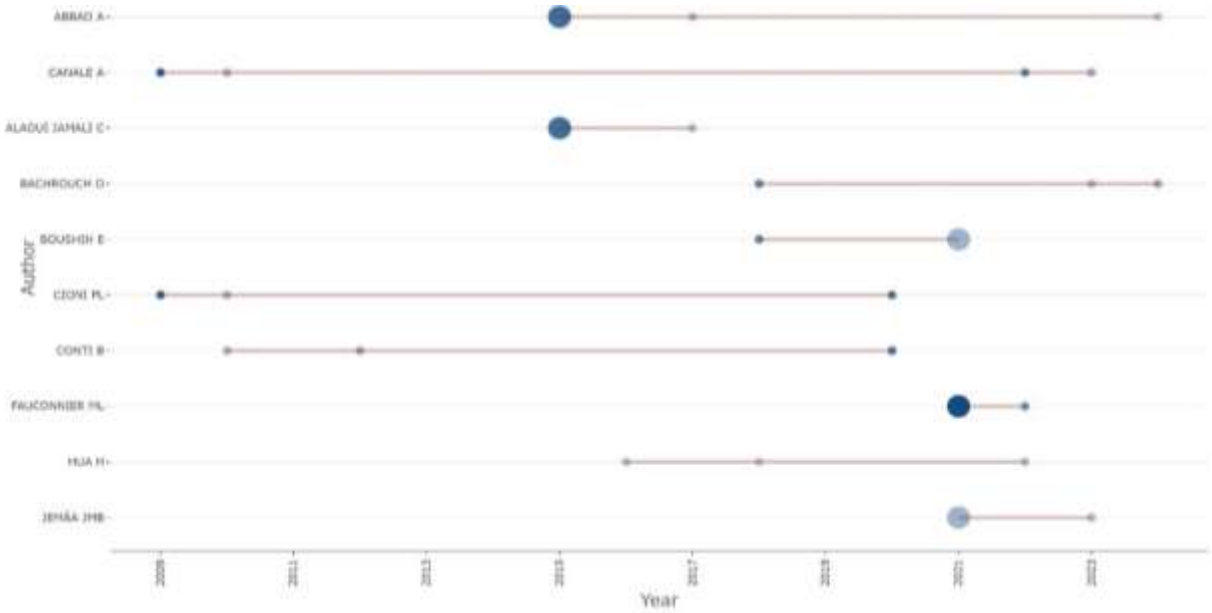


Şekil 3. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmaların yayınlandığı ilk on dergi ve H-indeksi

Bibliyometrik analiz sonuçlarını yazarlar açısından değerlendirdiğimizde ise Abbad A. ve Canale A.'nin dörder yayınla en üretken yazarlar olduğu görülmektedir. Her biri üç yayın ile alana katkıda bulunmuş 19 yazar bulunmakla beraber yayınlara katkıları açısından değerlendirildiğinde Alaoui Jamali C., Bachrouch O., Boushih E., Cioni P.L., Conti B., Fauconnier M.L., Hua H. ve Jemâa J.M.B. isimlerinin ön plana çıktığı görülmektedir. Verileri yazarların yayınlara zamana yayılmış katkıları açısından değerlendirdiğimizde ise Canale A., Cioni P.L. ve Conti B. gibi yazarların araştırma alanına erken dönemde katkı sağlamaya başladığı ve çalışmalarının yıllar içinde periyodik olarak devam ettiği görülmektedir (Şekil 4). Bu durum, söz konusu araştırmacıların konuyla uzun vadeli bir akademik ilgiyi sürdürdüklerini göstermektedir. Buna karşın Abbad A., Fauconnier M.L. ve Jemâa J.M.B. gibi yazarlar özellikle 2018 sonrası dönemde yoğun yayın faaliyeti yürütmüş; kısa sürede yüksek etkiye sahip yayınlar üretmişlerdir. Bu durum, son yıllarda artan bilimsel ilginin ve projelere dayalı araştırma dinamiklerinin bir sonucu olarak değerlendirilebilir. Yazarlar arasında Cioni P.L. ve Jemâa J.M.B. gibi isimler ise farklı yıllarda tekrar eden katkılarla sürekliliği temsil etmektedir. Özellikle 2020 ve sonrası, yeni araştırmacıların da katılımıyla yayın yoğunluğunun arttığı bir dönem olmuştur.

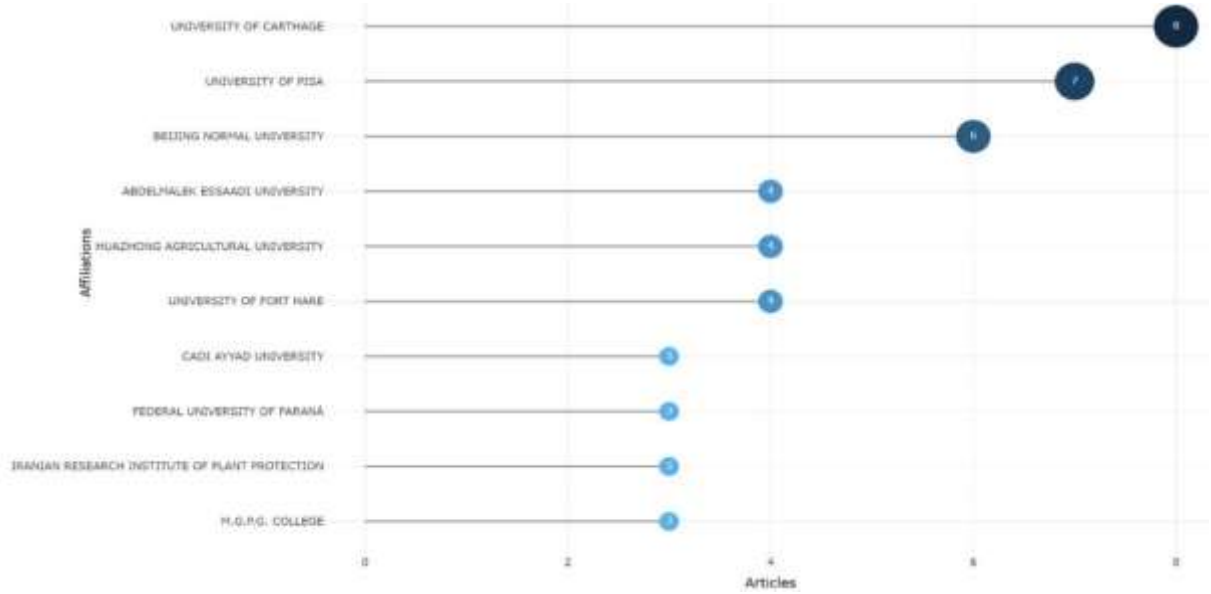
Çalışmalara en fazla katkı sağlayan kurum sekiz yayınla University of Carthage (Tunus) olmuş ve bunu sırasıyla University of Pisa (İtalya) ve Beijing Normal University (Çin) yedi ve altı yayınla takip etmiştir (Şekil 5). Bu üç üniversite, uçucu yağlar ve zararlı böcekler üzerine yapılan araştırmaların merkezinde yer almaktadır. Dördüncü sırada dörder yayınla Abdelmalek Essaadi University (Fas), Huazhong Agricultural University (Çin) ve University of Fort Hare

(Güney Afrika) bulunmaktadır. Ayrıca Fas (Cadi Ayyad University), İran (Iranian Research Institute of Plant Protection), Brezilya (Federal University of Paraná) ve Hindistan (M.G.P.G. College) gibi ülkelerden kurumlar da üçer yayınla önemli katkılar sağlamıştır. Yıllar açısından değerlendirdiğimizde ise University of Fort Hare, erken dönemde literatüre katkı sağlayan ilk kurumlardan biri olmuş ve bu katkısını uzun süre sabit bir seviyede sürdürmüştür. Zaman içinde en dikkat çekici çıkışı yapan kurum ise University of Carthage (Tunus) olmuştur. Bu kurum, 2016 sonrası hızlı bir yayın artışı göstermiş ve 2024 itibariyle toplam 8 yayına ulaşarak en üretken kurum haline gelmiştir.



Şekil 4. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda çalışan yazarların yıllara göre yayın katkılarını gösteren üretkenlik grafiği

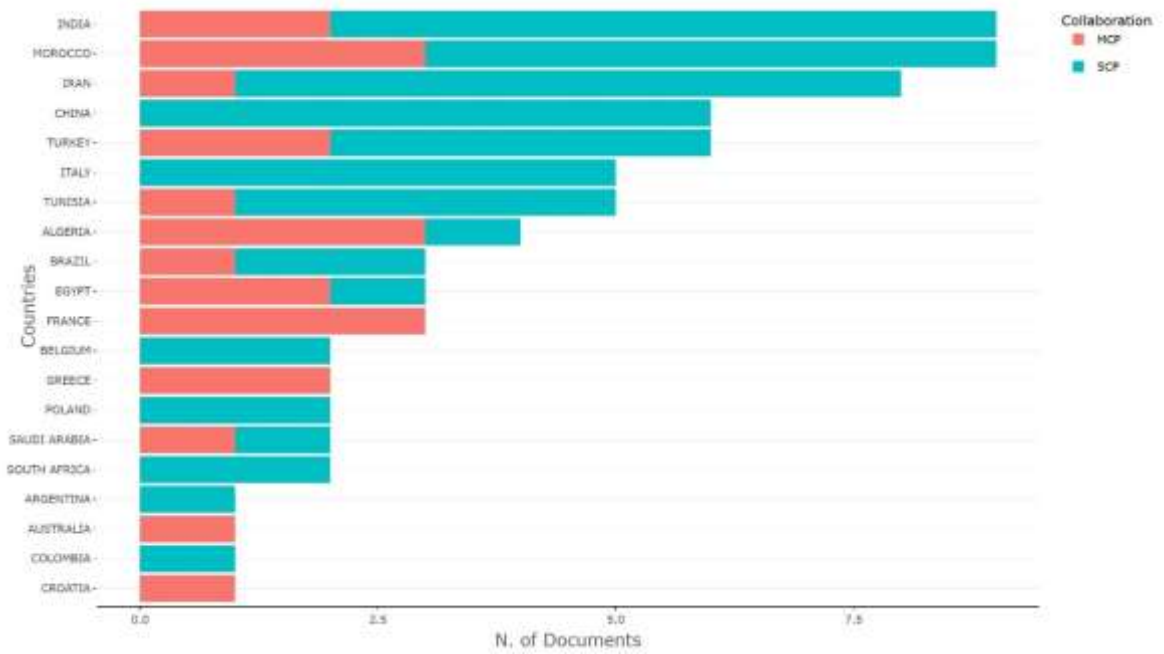
Benzer şekilde, University of Pisa (İtalya) da 2011 sonrası aktif olarak katkı sağlamış ve 2023 yılına kadar yayın sayısını 7'ye yükseltmiştir. Beijing Normal University (Çin), özellikle 2011 sonrası etkinliğini artırmış ve 2020'li yıllarda sabit bir yayın üretkenliği yakalamıştır. Huazhong Agricultural University (Çin) ile Abdelmalek Essaadi University (Fas) gibi kurumlar ise son yıllarda katkılarını artırarak dikkat çekmiştir. Bu kurumların 2023–2025 yıllarında hızlı bir ivmeyle yayın üretmeye başladıkları gözlemlenmektedir. Çalışmaların kurumsal ve zamansal dağılımı, konunun yalnızca bir bölgeye özgü olmadığını; Afrika, Asya ve Avrupa'daki kurumların da bu literatürde aktif rol aldığını ortaya koymaktadır. Özellikle Tunus, İtalya ve Çin'den gelen yayın yoğunluğu, ilgili bölgelerde konuya gösterilen bilimsel ilgiyi yansıtmaktadır.



Şekil 5. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalara katkı sağlayan kurumlar

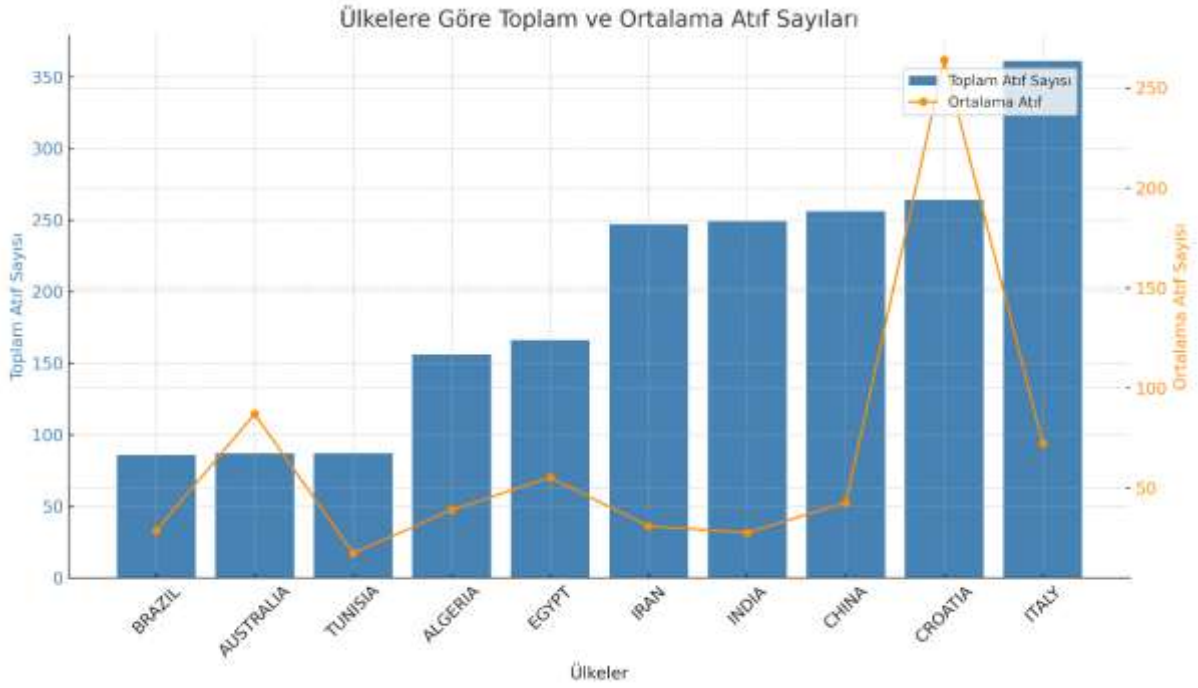
Bibliyometrik analiz kapsamında değerlendirilen çalışmalarda, sorumlu yazarların ülkesel dağılımı incelendiğinde, literatüre en fazla katkı sağlayan ülkelerin Hindistan ve Fas olduğu görülmektedir. Her iki ülke, analiz edilen yayınlar arasında 9'ar çalışmayla en üst sırada yer almıştır. Bu ülkeleri, 8 yayınla İran, 6'şar yayınla Çin ve Türkiye takip etmektedir. Bu bulgular, araştırma konusunun özellikle Güney Asya, Kuzey Afrika ve Orta Doğu ülkelerinde yoğun ilgi gördüğünü göstermektedir.

Ülkelerin yalnızca yayın sayılarıyla değil, aynı zamanda uluslararası iş birliği düzeyleriyle de analiz edilmesi anlamlıdır. Tek ülke içinde yapılan yayınlar (Single Country Publications – SCP) ile çok uluslu iş birliklerine dayalı yayınlar (Multiple Country Publications – MCP) karşılaştırıldığında; sırasıyla %77.8 ve %87.5 SCP oranı ile Hindistan ve İran yayınlarının büyük çoğunluğunu ulusal düzeyde üretildiği görülmektedir (Şekil 6). Bu durum, bu ülkelerde araştırmaların daha çok yerel araştırma altyapısı ve ulusal finansmanlar ile yürütüldüğünü düşündürmektedir. Buna karşılık, Fas ve Türkiye, MCP oranları bakımından dikkat çekmektedir. Fas'tan ve Türkiye'den çıkan yayınların %33.3'ü çok uluslu iş birliklerine dayanmaktadır. Bu oranlar, söz konusu ülkelerin uluslararası akademik ağlara daha açık olduğunu ve çok uluslu araştırma projelerinde aktif rol oynadığını ortaya koymaktadır. Özellikle Cezayir, yalnızca 4 yayına sahip olmasına rağmen bu yayınların %75'inin MCP kapsamında gerçekleşmiş olmasıyla öne çıkmaktadır. Bu durum sınırlı yayın sayısına rağmen güçlü uluslararası entegrasyonu işaret etmektedir. Sonuç olarak, sorumlu yazarın ülkelerine göre yapılan bu değerlendirme, araştırma alanının coğrafi çeşitliliğini ve uluslararasılaşma düzeyini ortaya koymakta; aynı zamanda iş birliğine dayalı bilimsel üretimin önemini vurgulamaktadır. Elde edilen bulgular, *Mentha* ve *Lavandula* gibi uçucu yağ kaynaklı bitkisel biyopestisitlerin araştırılmasında farklı bölgesel yaklaşımların ve iş birliği stratejilerinin etkili olduğunu göstermektedir.



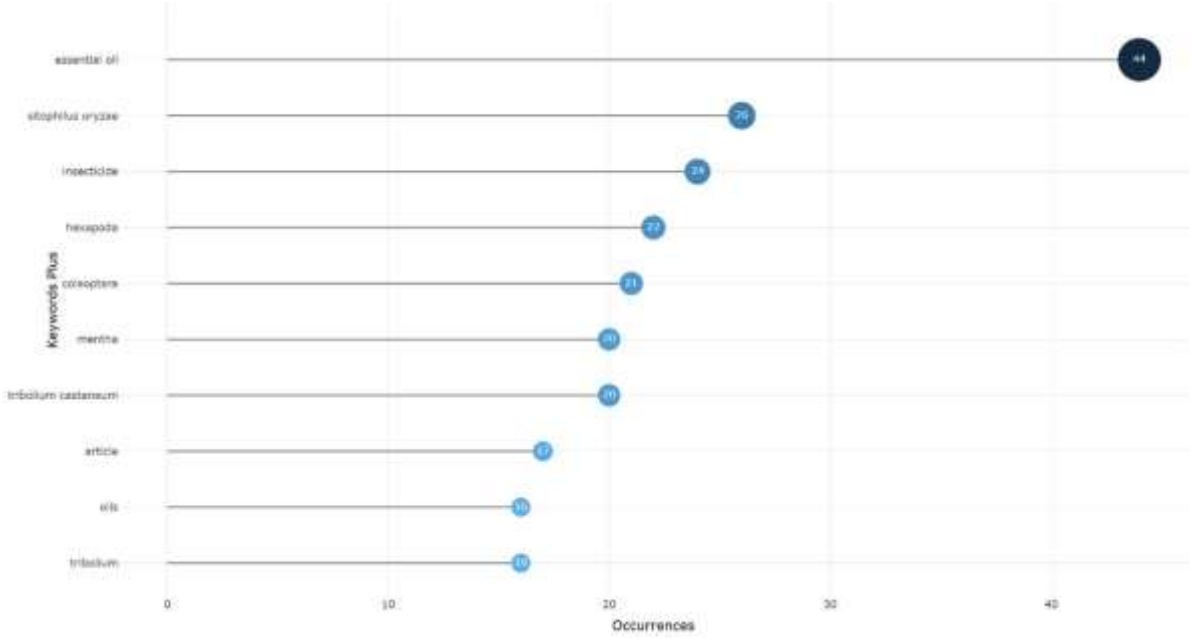
Şekil 6. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalara katkı sağlayan sorumlu yazarların ülkelere göre dağılımı

Yapılan bibliyometrik analiz kapsamında, araştırma alanında en yüksek atıf sayısına ulaşan ülkeler incelendiğinde İtalya beş farklı makalesine aldığı 361 atıfla en çok atıf alan ülke olarak öne çıkmaktadır (Şekil 7). Onu sırasıyla Hindistan, İran, Çin ve Hırvatistan sırasıyla 249, 247, 256 ve 264 atıf ile takip etmektedir. Atıf analizinde yalnızca toplam atıf sayısı değil, yayın başına ortalama atıf sayısı da önemli bir göstergedir. Bu açıdan bakıldığında, Hırvatistan, yalnızca bir yayından elde ettiği 264 ortalama atıfla öne çıkmaktadır. İtalya beş makale açısından ortalama 72.2 atıf ile literatürde oldukça görünür ve sık atıf alan çalışmalar üretmiştir. Buna karşın dokuzar makaleyle en üretimin gerçekleştiği Fas ve Hindistan sırasıyla ortalama 4.7 ve 27.7 atıf almış olup buna göre göreceli olarak bu çalışmaların yaygın etkilerinin düşük kaldığını söyleyebiliriz. Kuzey Afrika ülkelerinden Cezayir ve Mısır ortalama 39 ve 55.3 atıfla hem üretkenlik hem de etki açısından güçlü katkılar sağlamıştır. Tunus ve Brezilya ise sırasıyla 17.4 ve 28.7 atıfla daha mütevazı düzeyde katkı sağlamakla birlikte bölgesel çeşitliliğin sürdüğünü göstermektedir. Genel olarak bu veriler, alanın Avrupa (İtalya, Hırvatistan), Asya (Hindistan, İran, Çin) ve Afrika (Mısır, Cezayir, Tunus) kökenli çok uluslu ve etkili bir literatür ağı tarafından desteklendiğini ortaya koymaktadır. Sadece yayın sayısının değil, yayınların aldığı atıfların da dikkate alınması, ülkelerin bilimsel görünürlüğünü ve katkı kalitesini daha doğru değerlendirmeyi sağlamaktadır.



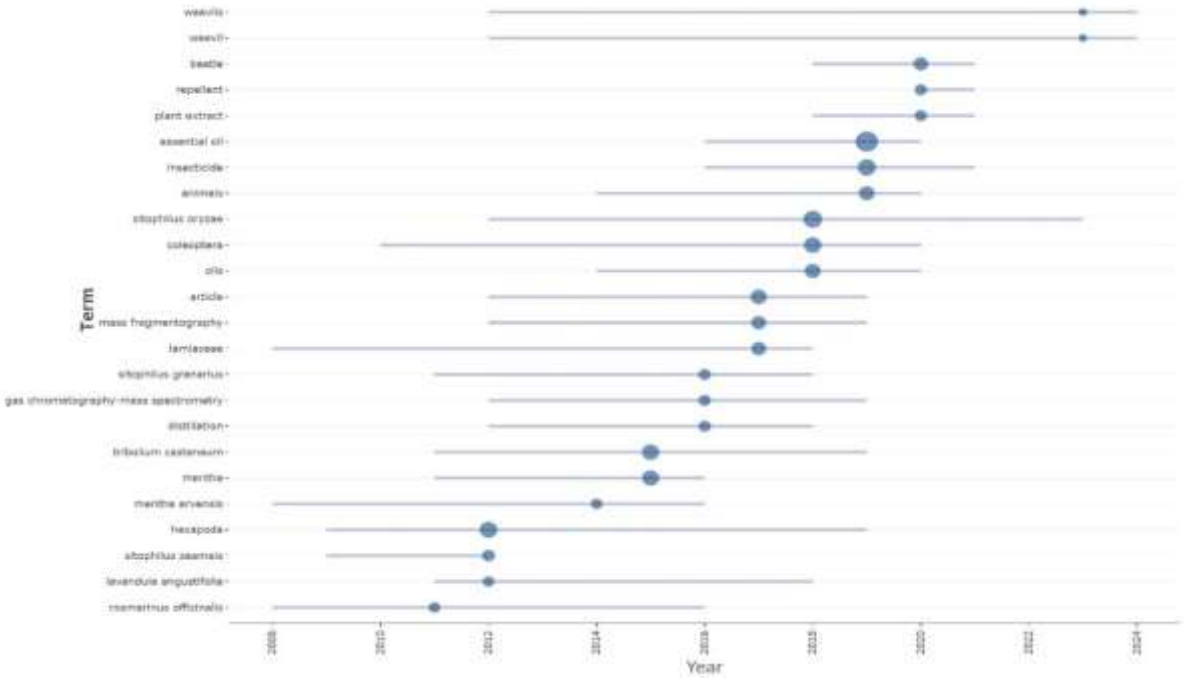
Şekil 7. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus*, *Tribolium*, *Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalara yapılan atıf sayılarının ülkelere göre dağılımı

Bibliyometrik analiz kapsamında incelenen literatürde en sık karşılaşılan terimlerin dağılımı, Keywords Plus verileriyle ortaya konmuştur (Şekil 8). Toplamda 44 çalışmada yer alan "essential oil" ifadesi açık ara farkla en sık kullanılan anahtar kelime durumundadır. Onu takip eden terimler arasında "*Sitophilus oryzae*" (26) ve "insecticide" (24) yer almakta; bu da uçucu yağların kullanım alanının doğrudan depo zararlısı türleri ve insektisit özellikleriyle ilişkili olduğunu ortaya koymaktadır. Ayrıca "hexapoda" (22) ve "coleoptera" (21) gibi taksonomik düzeyde sınıflandırmaları ifade eden terimler, çalışmalarda organizma odaklı bir yaklaşımın benimsendiğini göstermektedir. Alt sıralarda yer alan ancak yine de dikkate değer sıklıkta kullanılan "article" (17), "oils" (16) ve "tribolium" (16) gibi terimler, literatürün içeriksel çeşitliliğini desteklemektedir.



Şekil 8. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalarda en sık karşılaşılan terimlerin dağılımı

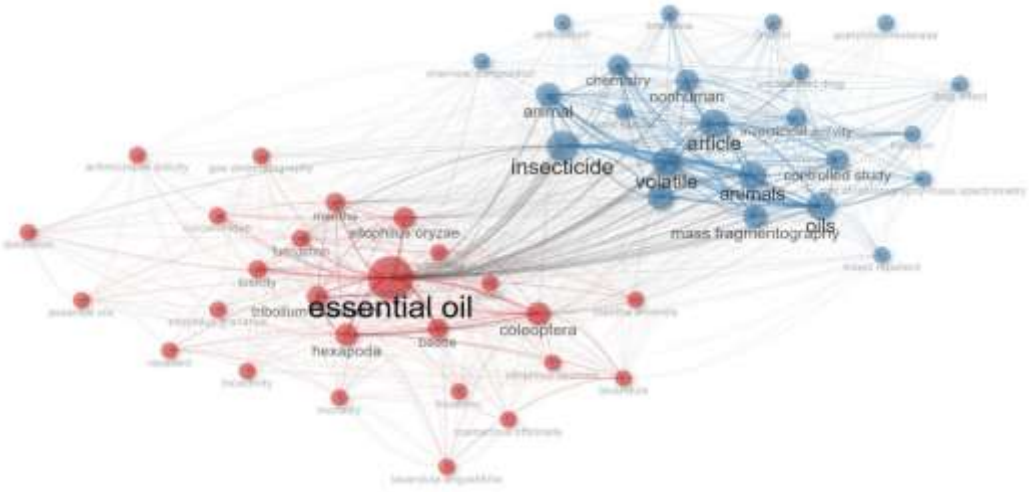
Araştırmalarda kullanılan başlıca anahtar terimlerin literatürdeki ilk belirme yılları ve sonraki süre boyunca kullanım sıklıkları Şekil 9'da görülmektedir. Her bir terim için çizilen yatay çizgi, terimin kullanıldığı zaman aralığını; dairelerin büyüklüğü ise belirli yıllarda terimin ne kadar yoğun kullanıldığını temsil etmektedir.



Şekil 9. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalarda kullanılan Keywords Plus verilerine göre en sık rastlanan terimlerin sıklık grafiği

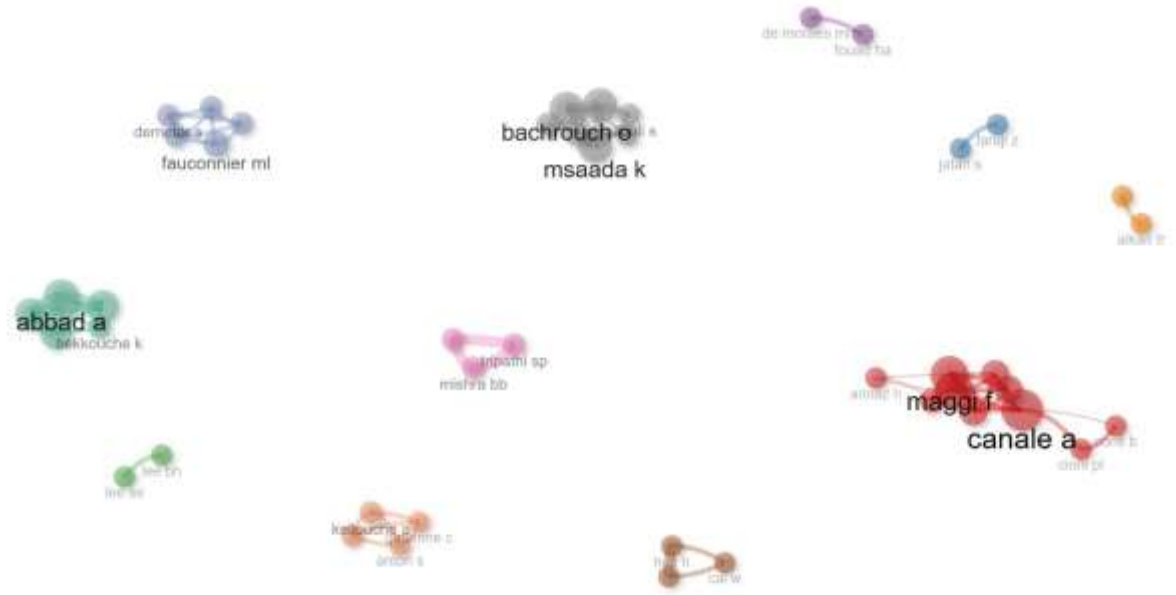
2012–2017 dönemi, *Mentha, Tribolium castaneum, Sitophilus zeamais* gibi hedef organizmalar ile *Rosmarinus officinalis, Lavandula angustifolia* ve *Mentha arvensis* gibi bitki türlerinin yoğun şekilde çalışıldığı bir dönem olarak öne çıkmaktadır. Özellikle "essential oil", "repellent", "plant extract" ve "insecticide" gibi anahtar kavramlar, bu dönemde daha yoğun biçimde literatüre yansımıştır. Zamana yayılan anahtar kelimeler arasında "gas chromatography–mass spectrometry", "distillation" ve "mass fragmentography" gibi teknik terimlerin varlığı, literatürde kullanılan metodolojilerin gelişmiş analitik yaklaşımlara dayandığını göstermektedir. Ayrıca "*Sitophilus oryzae*", "*Sitophilus granarius*" ve "*Tribolium castaneum*" gibi tür isimlerinin sürekliliği, bu organizmaların farklı çalışmalarda yaygın olarak hedef alındığını ortaya koymaktadır.

Yapılan çalışmalarda en sık birlikte kullanılan anahtar kelimeler arasında kurulan co-occurrence ağı, literatürde kullanılan temel kavramlar arasındaki ilişki yapısını ve araştırma alanının kavramsal haritasını ortaya koymaktadır. Analiz sonuçları, çalışma konusunun iki ana tematik küme etrafında şekillendiğini göstermektedir (Şekil 10). İlk olarak, biyolojik odaklı kümelenme, "essential oil", "*Sitophilus oryzae*", "*Tribolium castaneum*", "*Mentha*", "*Lavandula*", "repellent", "toxicity" ve "bioassay" gibi anahtar kelimeler etrafında toplanmıştır. Bu grup, uçucu yağların depo zararlıları üzerindeki biyoinsektisit ve repellent etkilerinin araştırıldığı çalışmaları temsil etmektedir. Özellikle zararlı türlerinin adı geçen bu kümelenme, entomolojik açıdan hedef odaklı ve pratik uygulamalara dönük çalışmaların ağırlığını göstermektedir. İkinci olarak, kimyasal ve analitik temelli kümelenme, "insecticide", "volatile", "mass fragmentography", "gas chromatography-mass spectrometry", "chemical composition" ve "limonene" gibi terimlerle temsil edilmektedir. Bu küme, uçucu yağların kimyasal bileşenlerinin belirlenmesi ve insektisit etki mekanizmalarının açıklanması amacıyla yapılan laboratuvar temelli araştırmaları yansıtmaktadır. Her iki küme arasında "essential oil", "insecticide" ve "animals" gibi terimlerin köprü rolü oynadığı görülmüştür. Bu anahtar kelimeler, disiplinler arası araştırmaların merkezi bileşenleri olup hem biyolojik hem de kimyasal içerikli çalışmaların ortak kavramsal çerçevesini oluşturmuştur. Sonuç olarak, analiz edilen literatürdeki anahtar terimler arasındaki birlikte geçme yapısı, araştırma alanının çok disiplinli doğasını yansıtmaktadır. Uçucu yağların bitki koruma, entomoloji, farmakoloji ve analitik kimya perspektifleriyle eş zamanlı olarak çalışıldığı anlaşılmaktadır.



Şekil 10. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalarda en sık birlikte kullanılan anahtar kelimeler arasında kurulan co-occurrence ağı

Yazarlar arası iş birliği ağı, araştırma alanında faaliyet gösteren bilim insanlarının oluşturduğu bilimsel toplulukları, merkezî figürleri ve bölgesel kümelenmeleri göstermektedir (Şekil 11). Grafik üzerinde her bir düğüm bir yazarı, bağlantılar ise ortak yazarlı yayınları temsil etmektedir. Küme renkleri ise belirli iş birliği gruplarını göstermektedir. Analize göre, Canale A., Maggi F., Conti B. ve Cioni P.L.'den oluşan kırmızı renkli küme, ağın en büyük ve en yoğun kümelenmiş iş birliği grubunu temsil etmektedir. Bu yazarlar, genellikle İtalya merkezli çalışmalarda bir araya gelmiş, çok sayıda ortak yayın üretmiş ve güçlü bir ağ yapısı kurmuştur. Diğer dikkat çekici bir diğer küme, Bachrouch O., Msaada K. ve Jemâa J.M.B. gibi yazarları içeren Tunus ve Kuzey Afrika odaklı gruptur. Siyah renkle temsil edilen bu yazarlar, kendi içinde sıkı bağlantılara sahiptir ve alanda bölgesel liderlik rolü oynamaktadır. Benzer şekilde, Abbad A. ve Bekkouche K.'nin öne çıktığı yeşil kümelenme, Cezayir merkezli çalışmaları yansıtmakta; Fauconnier M.L. – Demeter S. ikilisi ise daha çok Belçika/Fransa eksenindeki Avrupa merkezli araştırma iş birliklerini temsil etmektedir. Diğer yandan, Tripathi S.P. – Mishra B.B., Hua H. – Cai W. ve Jafari S. – Faraji Z. gibi ikili grupların daha küçük ölçekli ve bağımsız iş birliği ilişkileri kurduğu görülmektedir. Bu yapılar, daha az uluslararası ağ etkisine sahip olmakla birlikte, odaklanmış tematik araştırmaların örnekleri olabilir. Genel olarak ağın modüler yapısı, alanın bölgesel ve disiplinler arası kümelere ayrıldığını, ancak uluslararası çapta merkezi birleştirici figürlerin sınırlı kaldığını göstermektedir. Bu durum, araştırma alanında daha fazla disiplinler arası ve uluslararası ortaklıkların teşvik edilmesi gerektiğini ortaya koymaktadır.



Şekil 11. *Mentha* ve *Lavandula* bitkisel uçucu yağlarının *Sitophilus, Tribolium, Rhyzopertha* türleri üzerine etkisi konusunda yapılan çalışmalarda yer alan yazarların ortak yayınlarına dayalı iş birliği ağı haritası

6. SONUÇ

Bu çalışma, *Mentha* ve *Lavandula* türlerinden elde edilen uçucu yağların, önemli depo zararlıları olan *Sitophilus oryzae, Tribolium confusum* ve *Rhyzopertha dominica*'ya karşı kullanımına ilişkin bilimsel yayınları bibliyometrik yöntemlerle incelemiştir. SCOPUS veri tabanından elde edilen 100 akademik çalışmanın analizine dayanan bulgular, konunun 2001 yılından itibaren düzenli biçimde bilimsel literatürde yer bulduğunu ve 2011 sonrası dönemde

artan bir ivmeyle ele alındığını göstermektedir. Özellikle 2018 ve 2019 yıllarında ulaşılan yayın zirveleri, çevre dostu biyopestisitlere olan akademik ilginin güçlendiğini ortaya koymaktadır.

Yayınların yıllık büyüme oranı %2.93 olup, belgelerin ortalama yaşı 7.33 yıl olarak hesaplanmıştır. Belgelerin her biri ortalama 28.53 atıf almış; bu da alanın bilimsel etki bakımından dikkate değer bir görünürlüğe sahip olduğunu göstermektedir. Literatürde yer alan 441 yazar arasında sadece birinin tek yazarlı makale yayımlamış olması, araştırma konusunun iş birliği temelli yürütüldüğünü ortaya koymaktadır. Uluslararası ortak yazarlık oranı %33 düzeyindedir.

Ülke bazlı analizlerde, Fas ve Hindistan'ın 9'ar yayın ile en üretken ülkeler olduğu belirlenmiştir. Bu ülkeleri İran (8), Çin ve Türkiye (6'şar yayın) takip etmektedir. Uluslararası iş birliği oranları açısından Cezayir (%75 MCP) ve Fas ile Türkiye (%33.3 MCP) gibi ülkeler dikkat çekmektedir. En fazla atıf alan ülke İtalya (361 atıf) olurken, Hırvatistan tek bir yayından 264 atıf alarak ortalama bazda en yüksek değeri elde etmiştir. Kuzey Afrika (Fas, Tunus, Mısır, Cezayir) ve Asya (Hindistan, İran, Çin) ülkelerinin katkısı, çalışmanın coğrafi çeşitliliğini ve bölgesel önemini yansıtmaktadır.

Anahtar kelime analizleri, literatürde "essential oil", "Sitophilus oryzae", "insecticide" ve "repellency" gibi kavramların öne çıktığını göstermiştir. Co-occurrence ağı ve çok boyutlu ölçekleme (MDS) analizleri sonucunda, tematik olarak iki ana küme tanımlanmıştır: (i) uçucu yağların biyolojik etkilerine odaklanan çalışmalar ve (ii) bu yağların kimyasal bileşimlerinin analiziyle ilgili araştırmalar. Terimlerin zaman içindeki kullanım sıklığı, 2012–2017 döneminin kavramsal yoğunluk açısından kritik bir dönem olduğunu ortaya koymuştur.

Yazar ve kurum analizleri, Canale A., Abbad A. gibi isimlerin ve University of Carthage (Tunus), University of Pisa (İtalya), Beijing Normal University (Çin) gibi kurumların literatürde merkezi roller üstlendiğini göstermektedir. İş birliği ağı yapısı, bölgesel kümelenmelerin baskın olduğunu ancak uluslararası iş birliklerinin henüz sınırlı kaldığını göstermektedir.

Sonuç olarak, bibliyometrik veriler bu araştırma alanının disiplinler arası yapısını, artan bilimsel ilgisini ve çok yönlü uluslararası katılım potansiyelini ortaya koymaktadır. Uçucu yağlara dayalı biyopestisit araştırmaları, hem ekolojik hem de toksikolojik yönleriyle zengin bir bilimsel üretim alanı sunmakta ve sürdürülebilir tarım uygulamaları bağlamında önemini her geçen gün artırmaktadır.

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INVESTIGATION OF *IN VITRO* RESPONSES OF PARSLEY TO SALT STRESS

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ABSTRACT

In this study, the effects of different salt concentrations on the growth of plants were investigated under *in vitro* conditions. In the experiment, four different media (MYA, MYB, MYC, and MYD) were used, and increasing concentrations of salt (0, 100, 200, and 300 mM) were applied to these media. Stem length (mm), root length (mm), stem wet (g) and dry weight (g), and root wet (g) and dry weights were measured as plant growth parameters. According to the results obtained, a significant decrease in plant growth was observed as the salt concentration increased. The highest growth values were determined in the control group MYA medium and were measured as stem length 43.87 mm, root length 87.07 mm, stem wet weight 0.040 g, stem dry weight 0.004 g, root wet weight 0.0036 g and root dry weight 0.0012 g. The lowest values were recorded in MYD medium with the highest salt concentration. Statistical analysis showed that the differences between the media were statistically significant for most of the traits. These results indicate that increasing salt stress negatively affected the *in vitro* growth of parsley.

Keywords: Salinity, Parsley, *In vitro*

MAYDANOZ BİTKİSİNİN TUZ STRESİNE KARŞI *İN VİTRO* TEPKİLERİNİN ARAŞTIRILMASI

ÖZET

Bu çalışmada, *in vitro* koşullarda farklı tuz konsantrasyonlarının maydanoz bitkisinin gelişimi üzerindeki etkileri araştırılmıştır. Denemede dört farklı ortam (MYA, MYB, MYC ve MYD) kullanılmış ve bu ortamlara artan tuz (0, 100, 200 ve 300 mM) konsantrasyonları uygulanmıştır. Bitkisel gelişim parametreleri olarak gövde uzunluğu (mm), kök uzunluğu (mm), gövde yaş (g) ve kuru ağırlığı (g) ile kök yaş (g) ve kuru ağırlıkları ölçülmüştür. Elde edilen bulgulara göre, tuz konsantrasyonu arttıkça bitki gelişiminde anlamlı bir azalma gözlenmiştir. En yüksek gelişim değerleri kontrol grubu olan MYA ortamında belirlenmiş olup, gövde uzunluğu 43.87 mm, kök uzunluğu 87.07 mm, gövde yaş ağırlığı 0.040 g, gövde kuru ağırlığı 0.004 g, kök yaş ağırlığı 0.0036 g ve kök kuru ağırlığı 0.0012 g olarak ölçülmüştür. En düşük değerler ise en yüksek tuz konsantrasyonuna sahip MYD ortamında kaydedilmiştir. İstatistiksel analizler sonucunda ortamlar arasındaki farkların çoğu özelliğe göre istatistiksel olarak önemli olduğu belirlenmiştir. Bu sonuçlar, artan tuz stresinin maydanozun *in vitro* gelişimini olumsuz yönde etkilediğini göstermektedir.

Anahtar Kelimeler: Tuzluluk, Maydanoz, *In vitro*

GİRİŞ

Toprak besin eksiklikleri kuraklık ve tuzluluk gibi abiyotik streslerin zararlı etkilerini artırarak genel bitki sağlığı ve ürün verimliliği için önemli zorluklar yaratır (Bisht, 2025). Küresel ısınma ve iklim değişikliği, biyolojik çeşitlilik ve tarımsal üretim açısından dünya genelinde ciddi tehditler oluşturmaktadır. Tuzluluk, yüksek sıcaklık ve kuraklık gibi olumsuz çevresel stresler aracılığıyla tarımsal verimliliği önemli ölçüde azaltmaktadır (Boorboori ve ark., 2011; Moore ve ark., 2017; Pan ve ark., 2017; Pourraeisi ve ark., 2022; Boorboori ve Li, 2025). Genel olarak abiyotik stresler, tarımsal verimliliğin artırılmasında karşılaşılan en büyük engellerden biridir (Boorboori ve Zhang, 2023; Munns ve Gilliham, 2015). Bu stresler arasında tuz stresi, küresel ölçekte tarımsal üretim ve verim üzerinde en ciddi etkiye sahip olan başlıca çevresel sınırlamadır. (Zhu 2016; Malik ve Lal 2018; Van Zelm ve ark., 2020, Zhang ve Testerink 2020). Tuzluluk stresindeki artış, doğal etkenlerin (örneğin okyanusun zamanla geri çekilmesi veya minerallerin aşınması) yanı sıra özellikle tarımsal faaliyetler gibi insan kaynaklı faaliyetlerle tetiklenmektedir (Boorboori, 2023; Corwin, 2021). 2050 yılına kadar gezegende yaklaşık 10 milyar insan olacağı tahmin edilmektedir; bu da gıda gereksinimlerinde %50'lik bir artışa işaret etmektedir. Dünya nüfus artışı ve iklim değişikliğinin oluşturduğu tehdit, popüler çiftçilik yaklaşımlarını geçersiz kılıyor gibi görünmektedir (van Dijk ve ark., 2021; Zulfiqar ve Ashraf 2021; Abdelhameed ve ark., 2025). Günümüzde tuzlanma, dünyadaki ekilebilir arazilerin neredeyse üçte birini etkiliyor ve yetersiz sulama teknikleri, uygunsuz pestisit kullanımı ve endüstriyel kirliliğin durumu dünya çapında daha da kötüleştireceği tahmin edilmektedir (Abdelhameed ve ark., 2025). Dünyada tuzluluk stresinden en fazla etkilenen bölgeler kurak ve yarı kurak alanlardır (Sajyan ve ark., 2018; Siddiqui ve ark., 2019). Bu bölgeler, kara yüzeyinin üçte birini kaplamakta olup küresel tarımsal üretime önemli ölçüde katkı sağlayabilecek potansiyele sahiptir (Yurtseven ve ark., 2005; Muhammed ve Gomaa, 2012; Boorboori ve Zhang, 2022; Boorboori ve Li, 2025). Toprak tuzluluğu, özellikle korunaklı yetiştiricilik sistemlerinde sebze gelişimini ve hasadını tehdit eden, modern tarımın sürdürülebilirliğini sekteye uğratan küresel çapta önemli bir sorundur (Roeber ve ark., 2021). Günümüzde, sulanan tarım arazilerinin üçte birinden fazlası tuzlanma nedeniyle bozulmakta; bu durum, kontrolsüz iklim olayları, yetersiz drenaj ve yanlış sulama uygulamaları gibi çeşitli etkenlerle daha da kötüleşmektedir ve bu da gıda güvenliği açısından ciddi bir tehdit oluşturmaktadır (Roeber ve ark., 2021). Tuz stresi, sebze gelişimini yavaşlatmakta; hatta bitkilerde ölüm, kalite kaybı ve verim düşüşü gibi olumsuz sonuçlara yol açabilmektedir (Yang ve Guo, 2018). Bu nedenle, bitkilerin yüksek tuz konsantrasyonlarına karşı gösterdiği tepkileri anlamak büyük önem taşımaktadır (Peng ve ark., 2025).

Petroselinum crispum maydanoz, yaprak, kök ve tohumlarının ot ve baharat olarak, gıda işlemede ve ilaç endüstrisinde yaygın kullanımıyla Apiaceae (*Umbelliferae*) ailesine ait en önemli sebzeler arasındadır (Kadoglidou ve ark., 2025). Maydanoz hayati bir mutfak ve tıbbi bitki olup, önemli besinsel ve terapötik faydalar sağlar. Akdeniz bölgesinden gelen bu harika bitki, apigenin ve apiin gibi birçok fenolik bileşik ve flavonoidin yanı sıra, esas olarak miristisin ve apiolden oluşan uçucu yağlar ve kumarinlerin bir sandığıdır (Roy ve ark., 2025). Maydanoz antioksidan, antidiyabetik, anti-inflamatuar ve anti-apoptotik özelliklere sahiptir ve çeşitli fitokimyasallar (flavonoidler, kumarinler, karotenoidler, apiol, miristisin, ftalidler, seskiterpenler, monoterpenler ve askorbik asit) içerir. Esansiyel yağlar açısından zengindir ve bu nedenle hastalıkları ve alerjileri bastırmada önemli bir rol oynayabilir. Antioksidan özellikleriyle maydanoz, MTX (Metotreksat) kaynaklı beyin ve bağırsak hasarını iyileştirebilir. Bu nedenle maydanoz, insan diyetlerinde yaygın olarak bir takviye olarak kullanılır ve sağlıklı beslenmeye önemli bir katkıda bulunur (Sener ve ark., 2003; Mahmood ve ark., 2014; Maodaa ve ark., 2016; Ertaş ve ark., 202; Dursun, 2023; Yılmaz ve ark., 2024).

Bitki doku kültürü, artan besin değeriyle tarımsal üretime yönelik artan küresel talebi karşılamak için geliştirilen yenilikçi bir biyoteknolojik yaklaşımdır. Bu aseptik, *in vitro* teknik, bitki hücrelerinin, dokularının veya tüm bitkilerin kontrollü çevre ve besin koşulları altında yetiştirilmesine olanak tanır ve genetik olarak özdeş klonların üretilmesini kolaylaştırır. Bu yöntem, nesli tükenmekte olan bitki türlerinin korunması, ürün veriminin ve kalitesinin artırılması ve hastalıksız bitkilerin yıl boyunca üretilmesinin sağlanması için vazgeçilmezdir (Sidik ve ark., 2024).

Bu çalışmada, *in vitro* koşullarda farklı konsantrasyonlarda (0, 100, 200, 300 mM) NaCl içeren besin ortamlarının maydanoz bitkisi gelişimine etkilerinin belirlenmesi amaçlanmıştır.

MATERYAL VE METOT

Çalışma, Çukurova Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü Prof. Dr. Saadet BÜYÜKALACA doku kültürü laboratuvarında gerçekleştirilmiştir. Araştırmada D giant italiana maydanoz tohumları kullanılmıştır. Denemede tuzluluk stresi için MS (Murashige ve Skoog, 1962) besin ortamına değişik dozlarda (0, 100, 200, 300 mM) NaCl eklenerek ortamlar hazırlanmıştır (Çizelge 1). Maydanoz tohumları steril kabin içerisinde 20 dakika %20'lik sodyum hipoklorit çözeltisinde bekletilerek steril hale getirilmiştir. Kullanılan besin ortamları adlandırması ve ortam içerikleri Çizelge 1'de sunulmuştur. Steril kabin içerisinde besin ortamları petrilere dökülüp soğuyup katılaşmaya bırakılmıştır. Katılaşan ortamlara ekimi yapılmış ve 25 ± 2°C sıcaklık 3.000 lüx' ışık altında 16 saat aydınlık 8 saat karanlık periyotta büyütme odasına alınmıştır.

Çizelge 1. Ortamların adlandırılması

Dozlar	NaCl (mM)
MYA	0
MYB	100
MYC	200
MYD	300

Çalışmada kapsamında; gövde yaş ağırlığı (g), gövde kuru ağırlığı (g), kök yaş ağırlığı (g), kök kuru ağırlığı (g), gövde uzunluğu (mm) ve kök uzunluğu (mm) belirlenmiştir. Çalışmada incelenen parametrelerden elde edilen verilere SAS temeli üzerine kurulu JMP 8.1 istatistik paket programında tesadüf parselleri deneme desenine göre analiz edilmiştir.

BULGULAR VE TARTIŞMA

Çizelge 2'de değişik NaCl dozlarının maydanoz tohumlarındaki gövde yaş ağırlığı (g), gövde kuru ağırlığı (g), kök yaş ağırlığı, kök kuru ağırlıkları (g) gövde kök uzunlukları (mm) belirlenmiştir. Ortamlar arasındaki farklar, istatistiksel olarak önemli bulunmuştur.

Çizelge'e göre gövde yaş ağırlığı, en fazla MYA (0.040 g) ortamında saptanmıştır. Gövde kuru ağırlığı en yüksek MYA (0.004 g) ortamında görülürken bu ortamı MYB (0.003 g) izlemiştir. Kök yaş ağırlığı en fazla MYA (0.0036 g) en az MYD (0.0013 g) ortamında belirlenmiştir. Kök kuru ağırlığı en yüksek MYA (0.0012 g) ortamında elde edilmiştir.

Gövde uzunluğu, en fazla kontrol ortamı olan MYA (43.87 mm) kök uzunluğu MYA (87.07 mm) ortamında sağlanmıştır.

Woodward ve Bennett (2005), Eucalyptus camaldulensis üzerinde gerçekleştirdikleri bir çalışmada, büyüme ortamına NaCl ve absisik asit ekleyerek bitkinin 100 mM'ye kadar olan tuz konsantrasyonlarına uyum sağlayabildiğini tespit etmişlerdir. Bekheet ve ark. (2006) tarafından gerçekleştirilen bir çalışmada, soğan dokularının tuz stresine verdiği yanıtlar incelenmiş ve tuz oranının 4000 ppm'e kadar yükselmesiyle birlikte kuru ağırlık ve kuru madde miktarında artış gözlemlendiği, bu seviyeden sonra ise azalmaların meydana geldiği belirtilmiştir. Kurum ve ark. (2013), farklı kabak çeşitlerinde çeşitli tuzluluk seviyelerinin (0 "kontrol", 2, 4, 8 ve 12 dS m^{-1}) fide gelişimi üzerindeki etkilerini incelemiştir. Çalışmada kök ve sürgünlerin taze ve kuru ağırlıkları değerlendirilmiştir. Araştırma sonucunda, çözeltinin elektriksel iletkenliği arttıkça kök taze ve kuru ağırlıkları ile sürgün taze ve kuru ağırlıklarında azalma eğilimi gözlemlenmiştir. Karakoç ve Kale (2015), marul bitkisine NaCl ve $CaSO_4$ içeren sulama sularını 0, 2, 4 ve 6 dS/m düzeylerinde uyguladıkları çalışmada, tuzluluk arttıkça bitkinin yaş ve kuru ağırlıklarında azalma görüldüğünü bildirmişlerdir.Rezaei Nasab ve ark. (2016), lavanta bitkisi üzerinde tuzluluğun etkilerini araştırdıkları çalışmalarında, artan tuz konsantrasyonlarının kök ve sürgün kuru ağırlığı, kök ve sürgün uzunluğu, dal sayısı ve yaprak yüzeyi gibi morfolojik özelliklerde belirgin azalmaya neden olduğunu bildirmişlerdir. Mahawar ve ark. (2018), tuz stresi altında yetiştirilen roka bitkilerinin yaş ağırlıklarının 0.613 ± 0.0186 g ile 0.167 ± 0.0176 g arasında, kuru ağırlıklarının ise 0.2 ± 0.0115 g ile 0.0833 ± 0.0033 g arasında olduğunu bildirmiştir. Szekely-Varga ve ark. (2020), gerçekleştirdikleri çalışmada, iki farklı lavanta çeşidine uygulanan NaCl'nin, konsantrasyona bağlı olarak kök gelişimini engellediğini rapor etmişlerdir. Altuner ve ark. (2022), in vitro koşullarda tuz stresinin bazı arpa çeşitleri üzerindeki etkilerini incelemiştir. Çalışma sonucunda, artan tuz konsantrasyonlarına bağlı olarak kuru kök ağırlığında azalma meydana geldiği belirlenmiştir. Saraçoğlu ve Akat (2022), süs lahanasında üç farklı tuzluluk seviyesinin bazı kalite parametreleri üzerindeki etkilerini araştırmışlardır. Araştırma sonucunda, en düşük tuzluluk seviyesinde bitki çapı, bitki boyu ve görsel skorun en yüksek değerlere ulaştığı rapor edilmiştir.

Mevcut çalışmanın sonuçları literatürle kıyaslandığında benzer sonuçlar elde edildiği dikkat çekmektedir.

Çizelge 2. Farklı NaCl konsantrasyonlarının maydanoz bitkisinin gövde yaş kuru, kök yaş kuru ve gövde kök uzunluklarının belirlenmesi

Ortamlar	Gövde Yaş Ağırlığı (g)	Gövde Kuru Ağırlığı (g)	Kök Yaş Ağırlığı (g)	Kök Kuru Ağırlığı (g)	Gövde Uzunluğu (mm)	Kök Uzunluğu (mm)
MYA	0.040a	0.004a	0.0036a	0.0012a	43.87a	87.07a
MYB	0.026b	0.003b	0.0026ab	0.0007b	32.20b	55.47b
MYC	0.017c	0.002c	0.0019bc	0.0004bc	26.69c	35.15c
MYD	0.015c	0.001d	0.0013c	0.0002c	18.25d	28.10c

SONUÇ

Abiyotik stres faktörlerinden tuzluluk önemli bir sorun olarak gerek ülkemizde gerekse dünya için önemli bir sorun olarak göze çarpmaktadır. Yetiştiriclik sırasında tuzluluğu yüksek olan topraklarda öenmli derecede verim kaybına neden olmaktadır. Bu çalışmada *in vitro* koşullarda

farklı NaCl stresi koşullarında maydanoz bitkisinin gelişimi belirlenmiştir. Çalışma sonucunda herhangi bir tuz ilavesi yapılmayan ortamlarda bitki gelişimin yüksek olduğu bununla birlikte tuz konsantrasyonunun artması sonucu bitki gelişiminin yavaşladığı görülmüştür.

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EFFECTS OF INCREASING SALT CONCENTRATIONS ON THE MORPHOLOGICAL DEVELOPMENT OF BROCCOLI UNDER *IN VITRO* CONDITIONS

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ABSTRACT

This study was conducted to determine the morphological responses of *Brassica oleracea* var. *italica* (broccoli) to different salt (NaCl) concentrations under *in vitro* conditions. In this study, four different culture media (BRKA, BRKB, BRKC and BRKD) were established by adding increasing concentrations of NaCl (0, 100, 200 and 300 mM) to Murashige and Skoog (MS) basal nutrient media. Morphological parameters such as stem length (mm), root length (mm), stem wet (g) and dry weight (g), and root wet (g) and dry weight (g) were measured to evaluate the effects of salt treatments on plant growth. The data obtained showed that statistically significant decreases occurred in all growth parameters parallel to the increase in salt level. The highest values were determined in BRKA medium representing the control group and were recorded as stem length 70.52 mm, root length 81.28 mm, stem wet weight 0.2061 g, stem dry weight 0.0771 g, root wet weight 0.0187 g and root dry weight 0.0047 g. In BRKD medium with the highest salt level, these values were 48.72 mm, 55.17 mm, 0.1662 g, 0.0428 g, 0.0111 g and 0.0025 g, respectively. The results revealed that broccoli plants were sensitive to salt stress under *in vitro* conditions and increasing NaCl concentrations had suppressive effects on plant morphology.

Keywords: Salinity, Broccoli, *In vitro*, *Brassica oleracea* var. italica

IN VİTRO KOŞULLARDA ARTAN TUZ KONSANTRASYONLARININ BROKKOLİ BİTKİSİNİN MORFOLOJİK GELİŞİMİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışma, *Brassica oleracea* var. *italica* (brokoli) bitkisinin *in vitro* koşullarda farklı tuz (NaCl) konsantrasyonlarına verdiği morfolojik yanıtları belirlemek amacıyla yürütülmüştür. Araştırma kapsamında Murashige ve Skoog (MS) bazal besin ortamına artan NaCl (0, 100, 200 ve 300 mM) konsantrasyonları eklenerek dört farklı kültür ortamı (BRKA, BRKB, BRKC ve BRKD) oluşturulmuştur. Tuz uygulamalarının bitki gelişimi üzerindeki etkilerini değerlendirmek amacıyla gövde uzunluğu (mm), kök uzunluğu (mm), gövde yaş (g) ve kuru ağırlığı (g) ile kök yaş (g) ve kuru ağırlığı (g) gibi morfolojik parametreler ölçülmüştür. Elde edilen veriler, tuz düzeyindeki artışa paralel olarak tüm gelişim parametrelerinde istatistiksel olarak anlamlı azalmalar meydana geldiğini göstermiştir. En yüksek değerler kontrol grubunu temsil eden BRKA ortamında belirlenmiş olup, gövde uzunluğu 70.52 mm, kök uzunluğu 81.28 mm, gövde yaş ağırlığı 0.2061 g, gövde kuru ağırlığı 0.0771 g, kök yaş ağırlığı 0.0187 g ve kök kuru ağırlığı 0.0047 g olarak kaydedilmiştir. En yüksek tuz düzeyine sahip BRKD ortamında ise bu değerler sırasıyla 48.72 mm, 55.17 mm, 0.1662 g, 0.0428 g, 0.0111 g ve 0.0025 g olarak ölçülmüştür. Sonuçlar, brokoli bitkisinin *in vitro* koşullarda uygulanan tuz stresine karşı duyarlılık gösterdiğini ve artan NaCl konsantrasyonlarının bitki morfolojisi üzerinde baskılayıcı etkiler oluşturduğunu ortaya koymuştur.

Anahtar Kelimeler: Tuzluluk, Brokoli, *In vitro, Brassica oleracea* var. italica

GİRİŞ

Toprak tuzluluğu, dünyanın kara yüzeyinin yaklaşık %7'sini temsil eden 1100 Mha toprağı etkileyen küresel bir tehdittir (FAO, 2023). Çok faktörlü bir olgu olarak toprak tuzlanması, doğal jeokimyasal süreçler ve ikincil antropojenik faaliyetler yoluyla meydana gelmektedir (Singh, 2022). Toprak tuzluluğu, ürün verimliliğini olumsuz etkileyen en önemli küresel sorunlardan biridir. Tuzluluk, su stresi, sodyum (Na^+) ve klorür (Cl^-) gibi iyonların aşırı alımına bağlı sitotoksisite ve besin dengesizliği yoluyla bitki büyümesini ve gelişimini bozar . Ek olarak, tuzluluğa genellikle reaktif oksijen türlerinin (ROS) oluşumu nedeniyle oksidatif stres eşlik eder (Tsugane ve ark., 1999 ; Hernandez ve ark., 2001; Isayenkov, 2012; Isayenkov ve Maathuis 2019). Küresel ısınma ve iklim değişikliği, dünya çapında biyolojik çeşitlilik ve tarımsal üretim için ciddi tehditlerdir ve tuzluluk, yüksek sıcaklık ve kuraklık gibi istenmeyen çevresel stresler yoluyla tarımsal üretkenliği önemli ölçüde etkilemektedir (Boorboori ve ark., 2011; Moore ve ark., 2017; Pan ve ark., 2017 ; Pourraeisi ve ark., 2022; Boorboori ve Li 2025). Genel olarak, abiyotik stresler tarımda verimliliği artırmanın önündeki en önemli sınırlamalardır (Boorboori ve Zhang 2023; Munns ve Gilliham 2015) ve tuz stresi, dünyadaki tüm abiyotik stresler arasında tarımsal verim ve üretkenlik üzerinde en önemli etkiye sahip olan en kritik çevresel sınırlamadır. (Zhu 2016; Malik ve Lal 2018; Van Zelm ve ark., 2020, Zhang ve Testerink 2020). Tuzluluk stresindeki artış, doğal süreçler (okyanusun kademeli olarak geri çekilmesi veya minerallerin aşınması gibi) ve özellikle tarımsal faaliyetler olmak üzere farklı insan faaliyetlerinin etkisiyle yönlendirilir (Boorboori 2023; Corwin, 2021). Tuzluluk stresinden en çok etkilenen dünya bölgelerinin başında kurak ve yarı kurak alanlar gelmektedir (Sajyan ve ark., 2018; Siddiqui ve ark., 2019) ve bu alanlar kara kütlesinin üçte birini oluşturduğundan, küresel mahsul üretimine önemli bir katkı sağlayabilir (Yurtseven ve ark., 2005; Muhammed ve Gomaa 2012; Boorboori ve Zhang 2022; Boorboori ve Li 2025). Toprak tuzlanması, özellikle korumalı yetiştirme sistemlerinde sebze büyümesini ve hasadını tehdit eden ve çağdaş tarımın sürdürülebilir ilerlemesini engelleyen küresel bir sorundur (Roeber ve ark., 2021). Sulanan arazilerin üçte birinden fazlası tuzlanma nedeniyle bozulmaktadır. Eşi benzeri görülmemiş aşırı iklim, uygunsuz drenaj ve sulama sistemleri ve diğer bazı faktörlerle birlikte, ekili arazi tuzlanması sorunu daha da artmış ve gıda güvenliğini ciddi şekilde tehdit etmektedir (Roeber ve ark., 2021). Tuz stresi sebze büyümesini engeller ve hatta ölüme, kalite bozulmasına ve verim düşüşüne neden olur (Yang ve Guo 2018). Bu nedenle, bitkilerin yüksek tuzluluğa nasıl tepki verdiğini araştırmak kritik öneme sahiptir (Peng ve ark., 2025). Brokkoli (*Brassica oleracea* var. *italica*), daha iyi üretim ve niteliksel performans gösterdiği ılıman sıcaklıklara sahip bölgelerde olmak üzere dünyanın her yerinde yetiştirilen bir sebzedir. (Cecílio Filho ve ark., 2012; Torres ve ark., 2021). Brokkoli, dünya çapında sebze olarak yenen Brassicaceae ailesine ait iki yılda bir bitkidir . Bitkinin yenilebilir kısımları sap ve büyük çiçekli baştır. Brokkoli, C vitamini ve K vitamini açısından zengin bir kaynaktır. Ayrıca önemli miktarda B1 , B3, B5, B6 ve E vitamini içerir. Brokolide ayrıca folat , krom, magnezyum, fosfor, çinko, kalsiyum, demir, selenyum, proteinler ve omega-3 yağ asitleri bulunur. Brokoli ayrıca polifenoller, yani kaempferol , kuersetin glukozitleri, isorhamnetin , glukozinolatlar ve bunların türevleri gibi çok sayıda fitokimyasal içerir. Bunlar, antioksidan ve antikanser özelliklerinden ve diğer sağlık yararlarından sorumludur. Brokkoli, yüksek besin ve lif içeriği nedeniyle en sevilen yiyeceklerden biri haline gelmektedir. Çok sayıda epidemiyolojik çalışma, brokolinin bağışıklık modülasyonu, detoksifikasyon, göz sağlığı, kemik sağlığı ve antimikrobiyal ve antioksidan özellikler gibi diyet ve terapötik faydalarını doğrulamıştır (Nagraj ve ark., 2020). Bitki doku kültürü sistemleri, laboratuvarda kontrollü aseptik koşullar altında tüm bitkilerin, organların, dokuların veya hücrelerin yetiştirilmesine olanak tanımaktadır. Doku kültürü sistemi, bitki veya eksplant büyümesi için gerekli tüm besinleri,

enerjiyi ve suyu bazal ortam aracılığıyla sağlar. Ayrıca, kontrollü inkübasyon koşulları büyümeyi desteklemek için optimize edilmiş ışık ve sıcaklık ayarları sağlar (Phillips ve Garda 2019). Bu çalışmada, *in vitro* koşullarda farklı konsantrasyonlarda (0, 100, 200, 300 mM) NaCl içeren besin ortamlarının brokkoli bitkisi gelişimine etkilerinin belirlenmesi amaçlanmıştır.

MATERYAL VE METOT

Çalışma, Çukurova Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü Prof. Dr. Saadet BÜYÜKALACA doku kültürü laboratuvarında gerçekleştirilmiştir. Araştırmada Atlantis brokkoli tohumları kullanılmıştır. Denemede tuzluluk stresi için MS (Murashige ve Skoog, 1962) besin ortamına değişik dozlarda (0, 100, 200, 300 mM) NaCl eklenerek ortamlar hazırlanmıştır (Çizelge 1). Brokkoli tohumları steril kabin içerisinde 20 dakika %20'lik sodyum hipoklorit çözeltisinde bekletilerek steril hale getirilmiştir. Kullanılan besin ortamları adlandırması ve ortam içerikleri Çizelge 1'de sunulmuştur. Steril kabin içerisinde besin ortamları petrilere dökülüp soğuyup katılaşmaya bırakılmıştır. Katılaşan ortamlara ekimi yapılmış ve 25 ± 2°C sıcaklık 3.000 lüx' ışık altında 16 saat aydınlık 8 saat karanlık periyotta büyütme odasına alınmıştır.

Çizelge 1. Ortamların adlandırılması

Dozlar	NaCl (mM)
BRKA	0
BRKB	100
BRKC	200
BRKD	300

Çalışmada kapsamında; gövde yaş ağırlığı (g), gövde kuru ağırlığı (g), kök yaş ağırlığı (g), kök kuru ağırlığı (g), gövde uzunluğu (mm) ve kök uzunluğu (mm) belirlenmiştir. Çalışmada incelenen parametrelerden elde edilen verilere SAS temeli üzerine kurulu JMP 8.1 istatistik paket programında tesadüf parselleri deneme desenine göre analiz edilmiştir.

BULGULAR VE TARTIŞMA

Araştırma süresince, değişik tuzluluk konsantrasyonlarında brokkoli tohumlarının gövde yaş ağırlığı (g), gövde kuru ağırlığı (g), kök yaş ağırlığı, kök kuru ağırlıkları (g) gövde kök uzunlukları (mm) Çizelge 2'de sunulmuştur. Ortamlar arasındaki farklar, istatistiksel olarak önemli bulunmuştur.

Gövde yaş ağırlıkları bakımından, en yüksek ağırlık 0.2061 g ile BRKA ortamında gerçeleşirken bu ortamı sırasıyla 0.1781 BRKB ve 0.1725 g BRKC ortamları izlemiştir. Gövde kuru ağırlığı en yüksek BRKA (0.0771 g) ortamında belirlenirken en düşük değer konsantrasyonların artması ile birlikte BRKD (0.0428 g) ortamında görülmüştür. Kök yaş ağırlığı en fazla BRKA 0.0187 g ortamında elde edilmiştir. Kök kuru ağırlığı bakımından en yüksek BRKA (0.0047 g) en düşük BRKD (0.0025 g) ortamında sağlanmıştır.

Gövde uzunluğu, en fazla kontrol ortamı olan BRKA (70.52 mm) ortamında bulunmuştur. En düşük uzunluk ise BRKD (48.72 mm) ortamında saptanmıştır. Kök uzunluğu bakımından en yüksek kök uzunluğuna diğer incelenen parametrelerdeki gibi BRKA (81.28 g) ortamında tespit

edilmiştir. Ortamlar arasındaki en düşük kök uzunluğu ise BRKD (55.17 mm) ortamında elde edilmiştir.

Kurum ve ark. (2013), farklı kabak çeşitlerinde değişik tuzluluk düzeylerinin (0, "kontrol", 2, 4, 8 ve 12 dS m-1) fide büyümesi üzerine etkilerini belirlemiştir. Araştırmada kök taze ve kuru ağırlıkları, sürgün taze ve kuru ağırlıkları incelenmiştir. Sonuç olarak çözeltinin elektriksel iletkenliği arttığında kök taze ağırlığı, kök kuru ağırlığı, sürgün taze ağırlığı ve sürgün kuru ağırlıklarının azalma eğiliminde olduğu görülmüştür. Avcı ve ark. (2020), pamuk çeşitlerinde in vitro koşullarda tuz uygulamalarında, artan tuz konsantrasyonunun bitkinin yaş kök ağırlığında azalmaya neden olduğunu bildirmiştir. Altuner ve ark. (2022) *in vitro* tuz stresinin bazı arpa çeşitlerindeki etkilerini belirlemiştir. Deneme sonunda, tuz konsantrasyonlarının artması sonucu kuru kök ağırlığının azldığı tespit edilmiştir. Baktemur (2023), *in vitro* koşullarda değişik dozlarda (0, 50, 100, 150, 200, 250 mM) NaCl'nin kabak bitkisi üzerine etkilerini incelemiştir. Denemede, tuz miktarının arması kabak bitkisinin gelişimini yavaşlattığını bildirmiştir.

Çizelge 2. Farklı NaCl konsantrasyonlarının brokkoli bitkisinin gövde yaş kuru, kök yaş kuru ve gövde kök uzunluklarının belirlenmesi

Ortamlar	Gövde Yaş Ağırlığı (g)	Gövde Kuru Ağırlığı (g)	Kök Yaş Ağırlığı (g)	Kök Kuru Ağırlığı (g)	Gövde Uzunluğu (mm)	Kök Uzunluğu (mm)
BRKA	0.2061a	0.0771a	0.0187a	0,0047a	70.52a	81.28a
BRKB	0.1781b	0.0605b	0.0152b	0,0036b	61.12b	71.59b
BRKC	0.1725bc	0.0547bc	0.01347bc	0.0031b	53.31bc	65.14c
BRKD	0.1662c	0.0428c	0.0111c	0.0025c	48.72c	55.17d

SONUÇ

İn vitro koşullarda farklı NaCl stresi koşullarında brokkoli bitkisinin gelişimi üzerindeki etkileri incelenmiştir. Gövde yaş ağırlığı en yüksek BRKA (0.206 g) ortamında belirlenmiştir. Gövde kuru ağırlığı en yüksek en yüksek BRKA (0.0771 g) ortamında gerçekleşmiştir. Kök yaş ağırlığı en yüksek BRKA (0.0187 g), kök kuru ağırlığı en yüksek BRKA (0.0047 g) ortamında saptanmıştır. Gövde ve kök uzunlukları ise incelenen diğer özelliklerdeki gibi BRKA (Kontrol) ortamında en fazla elde edilmiştir. Çalışma sonucunda tuzluluk dozlarının artması bitki gelişimini yavaşlattığı dikkat çekmiştir.

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PRECISION LIVESTOCK FARMING: POTENTIAL AND RISKS OF USING DIGITAL TECHNOLOGY IN ANIMAL HUSBANDRY

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ABSTRACT

In recent years, there has been a growing trend toward technologies designed to support farmers in livestock management by continuously, automatically, and in real-time monitoring and following animal productivity, environmental impacts, and parameters related to animal health and welfare. Scientists have increasingly focused on technology-driven approaches that establish a close connection between the environment, technology, and people, while also addressing the needs for sustainability and resilience in agriculture and livestock production. Terms such as Industry 4.0, Agriculture 4.0, and Livestock 4.0—or alternatively, precision livestock farming, precision agriculture, and smart farming—have become increasingly widespread. Numerous studies have been conducted on technologies aimed at supporting livestock management through the continuous and automated monitoring of productivity, environmental factors, and animal health and welfare. This study aims to comparatively examine, from multiple dimensions, the implementation status and potential of digital technologies emerging under the concept of Precision Livestock Farming (Livestock 4.0), as well as their impacts, strengths, weaknesses, opportunities and risks regarding animal health and welfare.

Keywords: Precision Livestock Farming, Animal health and welfare, Effect, Benefit, Risk

HASSAS HAYVANCILIK: HAYVANCILIKTA DİJİTAL TEKNOLOJİ KULLANIM POTANSİYELİ VE RİSKLERİ

ÖZET

Hayvan verimliliğini, çevresel etkileri, hayvan sağlığı ve refahı parametrelerini düzenli, gerçek zamanlı ve otomatik bir şekilde izleyip takip ederek, çiftçileri süürü yönetiminde desteklemek üzere tasarlanan teknolojilere bir yönelim oluşmaktadır. Son yıllarda bilim insanları, teknoloji odaklı yaklaşımlara odaklanmakla birlikte, sürdürülebilirlik ve dayanıklılık ihtiyaçlarına odaklanan çevre, teknoloji ve insanlar arasında yakın bir bağlantı kuracak, tarım ve hayvancılık alanlarıyla da ilgilenmektedirler. Endüstri 4.0, Tarım 4.0 ve Hayvancılık 4.0 veya hassas hayvancılık, hassas tarım, akıllı tarım gibi terimler giderek daha yaygınlaşmaktadır. Hayvan verimliliğini, çevresel etkileri, hayvan sağlığı ve refahı parametrelerini düzenli, gerçek zamanlı ve otomatik bir şekilde izleyip takip ederek çiftçileri sürü yönetiminde desteklemek üzere tasarlanan teknolojilere üzerine birçok araştırma düzenlenmektedir. Bu çalışmada, Hassas Hayvancılık (Hayvancılık 4.0) kavramı altında gelişen dijital teknolojilerinin hayvancılıkta uygulanma durumu ve potansiyelinin incelemesi yanında bu uygulamaların hayvan sağlığı ve refahı üzerine etkileri, güçlü, zayıf yönleri ile fırsat ve riskleriyle farklı boyutlarda karşılaştırılmalı olarak ele alınması amaçlandı.

Anahtar Kelimeler: Hassas Hayvancılık, Hayvan sağlığı ve refahı, Etki, Yarar, Risk

GİRİŞ

Hayvansal kaynaklı ürünlere yönelik küresel talebin giderek artması, çiftçileri faaliyetlerini genişletmeye ve büyütmeye zorlamaktadır (Morrone et al., 2022). Hayvancılık sektöründe hayvan başına maksimum üretkenliğin hedeflendiği, üretim alanlarının kontrol edildiği yoğun ve uzmanlaşmış sistemlere doğru hızlı bir ilerleme yaşanmaktadır (Berckmans, 2017; Yaman ve ark., 2021). Hayvansal kökenli gıdaya talebin 2050 yılına kadar küresel düzeyde %70 artması beklenmektedir. Bu talep artışının çevreyi çok fazla etki etmeden karşılanması gerekmektedir (Berckmans, 2017; Schillings et al., 2021; Yaman ve ark., 2021). Hayvancılık devrimi diyebileceğimiz bu süreç yavaş başlayıp, hızlı bir büyüme ve ilerleme göstermiştir (Berckmans, 2017; Yaman ve ark., 2021). Artan çiftlik ölçeği ve hayvan sayısı gibi sebepler, çiftçilerin geçmişte kullandığı uygulamaların veya yöntemlerin yeni düzen içerisinde sürü yönetimini sağlamada yetersiz olmalarına zemin hazırlamaktadır (Schillings et al., 2021; Gezici ve ark., 2023). Büyük hayvan topluluklarından oluşan çiftliklerde hayvan sağlığının sürekli izlenmesi daha önemli bir konu haline gelecektir (Berckmans, 2017). Yetiştiricilerin, yönetmeleri gereken büyük sürüler içerisindeki hayvanları bireysel olarak izleyecek araç ve gereçlere sahip olmaları gerektiği gerçeğini kabul edilmektedir (Berckmans, 2017). Hayvan verimliliğini, çevresel etkileri, hayvan sağlığı ve refahı parametrelerini düzenli, gerçek zamanlı ve otomatik bir şekilde izleyip takip ederek, çiftçileri sürü yönetiminde desteklemek üzere tasarlanan teknolojilere bir yönelim oluşmaktadır (Schillings et al., 2021; Morrone et al., 2022). Bu konular, ulusal ve uluslararası hukuk tarafından yoğun bir şekilde üzerinde çalışılan hassas konulardır. Bu konuların kontrol edilmesine yönelik yöntemlerin hızlı, etkili ve verimli olması gerekliliğini doğurmaktadır (Schillings et al., 2021; Morrone et al., 2022).

Son yıllarda bilim insanları, teknoloji odaklı bu yaklaşımlara odaklanmakla birlikte, insanlar sürdürülebilirlik ve dayanıklılık ihtiyaçlarına odaklanan çevre, teknoloji ve insanlar arasında yakın bir bağlantı kuracak, tarım ve hayvancılık ile ilgilenmektedirler (Vázquez-López et al., 2021; Kraft et al., 2022). Endüstri 4.0, Tarım 4.0 ve Hayvancılık 4.0 veya hassas hayvancılık (PLF, Precision Livestock Farming), hassas tarım, dijital tarım, akıllı tarım gibi terimler giderek daha yaygınlaşmaktadır. Bugüne kadar çeşitli ülkeler ve büyük dünya kuruluşları bu terimleri sürdürülebilir ve kullanıcı dostu çiftlik yönetiminin geliştirilmesinde temel taşları olarak kullanmaktadır (Schillings et al., 2021; Vázquez-López et al., 2021; Morrone et al., 2022).

Bu çalışmada, Hassas Hayvancılık (Hayvancılık 4.0) gibi gelişen dijital teknolojilerinin hayvancılıkta uygulanma durumu ve potansiyelinin incelemesi yanında bu uygulamaların hayvan sağlığı ve refahı üzerine etkileri, yararları ve riskleri gibi konular farklı boyutlarda karşılaştırılmalı olarak ele alınması amaçlandı.

Teknoloji Kullanmanın Potansiyeli ile Hayvan Sağlığı ve Refahı Üzerine Yararları

Hayvan yetiştiriciliğinde bulaşıcı hastalıklar ve topallık gibi önemli sağlık sorunları son derece yaygındır. Çiftliklerdeki ekonomik kayıpların en aza indirilmesi bağlamında bu tür durumların erken tespiti için teknolojinin kullanılması büyük avantaj sağlamaktadır. Hayvan yetiştiricilerinin hayvanlarının refahını izlemelerine yardımcı olacak bu "akıllı teknolojilerin" büyük potansiyeline sahip olduğu bildirilmektedir. Birçok ülke sürdürülebilir tarıma yönelik stratejilerin bir parçası olarak bu teknolojilerin gelişimine yatırım yapmaktadır (Schillings et al., 2021; Morrone et al. 2022; Kraft et al., 2022). Hassas hayvancılık, nesnelerin interneti (IoT), büyük veri, elektrikli araçlar (EV), 3D baskı, bulut bilişim, yapay zeka (AI) ve siber-fiziksel sistemler gibi teknolojik yenilikleri içeren bir girişimdir (Morrone et al. 2022). Sensörler, kameralar veya mikrofonlar gibi teknolojileri kullanan çeşitli sistemler, hayvanlar üzerinde tespit edilen verileri veya anormallikleri, çiftçilere çeşitli cihazlar (örneğin telefonlar,

bilgisayarlar veya tabletler) aracılığıyla doğrudan iletebilmekte ve çiftçilerin erken müdahale etmesine olanak sağlamaktadır (Schillings et al., 2021; Morrone et al. 2022; Kraft et al., 2022).

Hayvancılık söz konusu olduğunda çevre ve sosyo-ekonomiyi sürdürülebilirliğin boyutlarında ele alınması gerekmektedir, ayrıca hayvan sağlığı ve refahı da sürdürülebilirliğin önemli unsurlarıdır. Tüm bu teknolojilerin hayvan sağlığı ve refahı üzerine faydaları; hayvan sağlığının iyileştirilmesi, antibiyotik kullanımının azaltılması ve bazen sistemlerde hastalık salgınlarının önleyecek erken müdahale gibi yönetim kararlarının desteklenmesi şeklinde sıralanmaktadır. Ek olarak, hayvanları bireysel olarak izlenmesi, örneğin, vücuda giyilebilir cihazların kullanımı, hayvanların özel ihtiyaçlarının daha iyi anlaşılmasına yardımcı olarak kullanılabilmektedir (Schillings et al., 2021; Kraft et al., 2022).

İnsan-hayvan ilişkisi hem hayvan refahını hem de üretkenliği etkileyebilecek önemli bir faktördür. Bakıcıların hayvanlarına karşı tutumları veya davranışları, hayvanların insanlardan korkmasına, stres yaşamasına verimlerinin ve verimliliği de etkilenmesine sebep olabilmektedir (Hemsworth, 2003; Waiblinger ve ark., 2006). Hassas hayvancılık teknolojileri, insan-hayvan etkileşimlerini içeren belirli görevleri kolaylaştırmak ve/veya değiştirmek ve yetiştiricilerin hayvanlarını bireysel gözlemlenmesi için harcadığı zamanı azaltmak için kullanılmaktadır (Berckmans, 2017; Schillings et al., 2021).

Hassas hayvancılıkta kullanılan teknolojiler ile hayvanların davranışları doğrudan hayvan üzerinde bulunan biyosensörler aracılığıyla sürekli olarak ölçülmektedir. Bu tekniğin bazı avantajları vardır: hayvana fiziksel bir temas olma olasılığı, enfeksiyon veya hastalık bulaşma riski, ölçüm yapılırken hayvanın tepkisini etkileme riski yoktur, ayrıca tek bir veya mikrofon kamera kullanılarak maliyetler azaltılabilir (Berckmans, 2017).

Çiftlik yönetimini iyileştirmek için bu teknolojiler ile elde edilen verilerin gerçek zamanlı entegrasyonunun, çiftçilikte veriye dayalı karar alınmasına sağlamaktadır (Cabrera et al., 2020). Yeni teknolojilerden üretilen tüm bu veriler, doğru işlendiğinde yönetimin karar verme sürecine yardımcı olarak çiftliğe özgü modellerin geliştirilmesi için bir fırsat sunmaktadır (Cabrera et al., 2020). Sadece büyük ölçekli işletmelerde değil, küçük ölçekli çiftliklerde bile dijitalleşme, işi basitleştirme, esnekliği artırma ve yüksek profesyonel düzeyde uzmanlaşmış bilgi ve karar desteği sağlama konusunda büyük bir potansiyele sahip olduğu bildirilmektedir (Kraft et al., 2022; Gezici ve ark., 2023).

Uygulamada Karşılaşılan Riskler ve Zorluklar

Endüstriyel üretimde hassasiyeti artırmak için teknoloji ve otomasyondan yararlanmanın genel prensibi hassas hayvancılık uygulamaları kolayca aktarılabilir olmasına rağmen, ilgili prosedürlerini oluştururken çok dikkatli ve titiz çalışılması gereken bazı sorunların olduğu da göz ardı edilmemesi gerekmektedir (Goller et al., 2021; Morrone et al., 2022). Dijital teknolojinin çiftçiler ürerim süreçleri olumlu etkilerinin yanında barındırdığı potansiyel riskleri sıralamakta fayda bulunmaktadır. Bazı insanlar ve çiftçiler, hassas hayvancılık teknolojileri kullanımının çiftliklerin işleyişini temel olarak değiştirmesinden dolayı bazı etik kaygılar dile getirmektedirler. Ayrıca, tarımsal kar marjları genellikle düşük olduğundan, bu tür teknolojilerin maliyeti, tarım operasyonlarının karlılığını azaltabileceği ve kırsal bölgelerde internet bağlantısının eksikliği, bu tür sistemlere erişimi zorlaştırabileceği gibi kaygılar dillendirilmektedir (Morrone et al. 2022; Gezici ve ark., 2023). Bu teknolojiler grup düzeyinde alınan yönetim kararları ile hayvan refahı tespit edilmesinde faydalı olabilirken, farklı beslenme veya tedavi gereksinimleri olan bireylerin refahı için zararlı olabileceğinden verilerin yorumlanması dikkatli yapılması gerekliliği önemli bir endişe yaratmaktadır (Schillings et al., 2021). Diğer endişe ise, özellikle insanlara alışma fırsatlarının zaten sınırlı olduğu, fazla sayıda

hayvanın bulunduğu yetiştirme sistemlerinde insan-hayvan ilişkisinin hayvan refahı üzerindeki potansiyel bir etkisini bir sorun yaratabilmesi üzerinedir (Schillings et al., 2021).

Dijital teknolojilerin kullanımı, tüm paydaşlar için güvenilir teknolojiye ilişkin etik mevzuatlara, yönergelere ihtiyaç bulunmakta olup, bu yönergelerin sektöre özgü uygulaması aciliyeti de bulunmaktadır (Kraft et al., 2022; Gezici ve ark., 2023).

Dijitalleştirilmiş çiftliklerin yönetimi için çiftçilerin geleneksel tarım bilgilerini ve teknolojik okuryazarlığı içeren detaylı bir anlayışa sahip olmaları gerekmektedir. Genç çiftçilerin bu anlayışı nasıl geliştirdikleri henüz belirsizdir ve bu nedenle mesleki ve akademik okulların geleneksel tarımın yanı sıra dijital tarımı da kapsaması önemlidir (Goller et al., 2021).

Hayvancılıkta dijital destekli veya otonom üretimi sistem ve teknolojilerin kullanımı, yalnızca çiftliklerde değil, aynı zamanda onları çevreleyen tüm ilgili meslek mensuplarının, alanda işletme ve kurumlarda da gelişmiş doğrultusunda gerekli bilgi ve becerilere sahip olması gerekmektedir (Goller et al., 2021; Kraft et al., 2022; Morrone et al., 2022).

Hayvancılık yönetim teknolojileri kullanımı; geçiş maliyeti, hem donanım hem de yazılım maliyeti, teknolojinin etkili bir şekilde uygulanabilmesini sağlamak için ek enerji, internet bant genişliği veya ek ekipman maliyeti, eğitim ve uygulama süreci ve maliyeti ile çiftçilerin hatalarından kaynaklı kayıpları da içerebilmektedir. Çiftçiler, sürekli olarak maliyetleri potansiyel faydalara göre değerlendirecek, tüm bu yatırım ve çabaların geri dönüşü mantıklı olmadığı sürece, bu teknolojiyi benimsemeleri zor olacaktır (Neethirajan & Kemp, 2021; Gezici ve ark., 2023).

Fırsatlar, Öneriler ve Sonuç

Teknolojinin sürekli olarak gelişmesi insanların daha ucuz ve etkili cihazlara sahip olmalarına olanak sağlamaktadır. Bu nedenle, çiftlikler ve hayvancılık endüstrisi de teknolojiyi benimsemeye başlayarak önümüzdeki yıllarda bu sorunları aşabilecektir. Özellikle, internetin yaygınlaşmasıyla birlikte günlük yaşamımızda teknolojik ekipmanların kullanımı büyük ölçüde artmaktadır. Bu teknolojilerin çiftliklerde de yaygınlaşması kaçınılmaz olduğu ön görülmektedir (Morrone et al. 2022). Taşınabilir sensörler, hayvanların GPS konumlandırması ve çeşitli yazılım uygulamaları, hayvancılık ekonomisinin her alanında da dijital ilerlemelerin kullanımına olanak sağlayacağı bildirilmektedir (Kraft et al., 2022).

Çiftçileri bu dijitalleşme sürecini başarıyla yürütmesi onlara uluslararası pazarlarda rekabet avantajı sağlayacağı, uluslararası etik ve hayvan refah standartlarına uyumu kolaylaştıracağı ve tarım ve hayvancılık teknolojilerine yönelik yeni iş fikirleri ve girişimcilik fırsatları ortaya çıkaracağı da öngörülmektedir (Berckmans, 2017; Morrone et al. 2022; Kraft et al., 2022)

Sonuç olarak; Hassas Hayvancılık (PLF) tabanlı dijital teknolojiler, hayvanların davranışlarını ve sağlık durumlarını daha yakından izlemeyi mümkün kılarak hayvan refahının iyileştirilmesine katkı sağlamaktadır. Araştırmalarda, hayvan sağlığı ve refahına yönelik bu dijital uygulamaların yararları ve fırsatları kadar, zorluk ve riskleri de ortaya koymakta ve artıları ile eksileri aşağı yukarı dengeli olduğu bildirilmektedir. Ancak artan küresel nüfus ve hayvansal gıda talebi, yakın gelecekte hayvancılık sektörünü dijital teknolojilerin daha hızlı ve yaygın bir şekilde entegrasyonuna zorlayacağı; bu da Hassas Hayvancılık / Hayvancılık 4.0'a geçiş sürecini hızlandıracağı ön görülmektedir. Günümüzde Hayvancılık 5.0 kavramı ortaya çıkmış olup, hayvancılıkta Yapay Zeka teknolojilerinin kullanılacağı son evre olan İleri Hayvancılığın kavşağında olunduğu da vurgulanması gerekmektedir.

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LEARNING RATE SENSITIVITY IN TRANSFORMER MODELS: A CASE STUDY IN NEURAL MACHINE TRANSLATION

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ABSTRACT

Transformer architecture, which fundamentally differs from traditional deep learning models such as RNNs and CNNs by leveraging self-attention mechanisms rather than recurrence or convolution. This design allows for better parallelization and long-range dependency modeling, making Transformers particularly effective in sequence-to-sequence tasks such as machine translation. In this study, a bilingual English-German dataset was selected to systematically evaluate the impact of the learning rate on Transformer performance. A series of training runs were performed using learning rates ranging from 1e-2 to 1e-7 to systematically evaluate the impact of learning rate, a critical hyperparameter for optimization stability and convergence. The results reveal several noteworthy trends regarding the effect of learning rate on model performance. A relatively high learning rate (1e-3) facilitated rapid initial convergence; however, it also introduced significant instability, likely due to excessive parameter updates that caused the optimizer to overshoot optimal minima in the loss surface. Conversely, an extremely low learning rate (1e-6) yielded negligible improvements in performance, as evidenced by the slow and nearly parallel decline in training and validation losses. Although the 1e-2 learning rate yielded relatively competitive accuracy and faster computation compared to 1e-3, its persistently elevated loss values indicated unstable convergence behavior; conversely, extremely low learning rates, such as 1e-7, resulted in substantially reduced accuracy and extended computation times, illustrating the delicate balance required in learning rate selection. This behavior is indicative of underfitting, stemming from insufficient updates to the model's parameters. However, the most balanced and stable performance was observed at a learning rate of 1e-4, which achieved smooth convergence, strong alignment between training and validation metrics and consistent loss reduction throughout training. This outcome highlights the importance of selecting an appropriate learning rate, as it significantly influences both optimization stability and model generalization. Furthermore, these findings empirically support theoretical principles regarding learning rate selection in deep learning, demonstrating that intermediate values—particularly 1e-4 in this configuration—can effectively balance convergence speed and solution quality. Therefore, this study contributes to the growing body of research emphasizing the necessity of systematic hyperparameter tuning in neural network training, especially for Transformer-based models applied to sequence-to-sequence tasks.

Keywords: Transformer Architecture, Machine Learning Models, Deep Learning, Neural Machine Translation, Learning Rate

Introdcution

Deep learning is a critical research area with broad applications. It is extensively used in various disciplines today, including natural language processing(Islek, Katirci, and Celik 2024), social sciences(Çelik and Çınar 2021)(Celik and Cinar 2021), medicine(Tuncer et al. 2024), materials science(KATIRCI and TEKİN 2022) and particularly neural machine translation (Ott et al. 2018)(Karaca and Aydın 2023).

Deep learning research encompasses a diverse array of neural network architectures, notably recurrent neural networks (RNNs), including Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) models. Numerous studies have conducted comparative analyses of RNN (Çelik, Katırcı, and İşlek 2024), LSTM (Gupta et al. 2021) and GRU GRU (Islek, Katirci, and Celik 2024) architectures to evaluate their respective strengths and limitations in various sequence modeling tasks (Cai et al. 2019). Although these techniques achieved moderate success in processing sequential data, they exhibited significant limitations, particularly in terms of limited parallelization capabilities and inefficiencies in modeling long-range dependencies.To overcome these constraints, the Transformer architecture(Vaswani et al. 2017) was introduced in 2017, which was based on the self-attention mechanism. This groundbreaking architecture eliminated the sequential processing constraints of RNNs, enabling the direct modeling of dependencies between any two tokens in a sequence. Work with the Transformer significantly improved translation quality, primarily due to its enhanced parallel computing capabilities and its effectiveness in capturing long-range dependencies.

The performance of deep learning models is influenced by various components, including architectural choices, data characteristics and optimization strategies. Among these, the learning rate stands out as a critical hyperparameter, particularly during the backpropagation process, where it determines the magnitude of weight updates. It significantly affects convergence speed and the overall effectiveness of neural networks (Wu and Liu 2023). An optimal learning rate facilitates faster convergence and helps avoid local minima, whereas a poorly chosen rate can cause slow training or divergence. Hence, many studies have focused on learning rate schedules, such as step decay, exponential decay and adaptive methods like Adam (Liu et al. 2020) or RMSprop (Hermann et al. 2015), to improve training efficiency and stability across various tasks. In the field of deep learning, the careful selection of the learning rate is a critical factor that influences model optimization and performance. Despite significant progress in adaptive learning strategies and comprehensive hyperparameter tuning methodologies, there is a notable lack of focused, systematic, analytical studies assessing the impact of fixed learning rates on complex architectures, such as Transformer models. To address this critical gap, the present study provides a thorough analysis of a wide range of fixed learning rates, specifically from 1e-2 to 1e-7. The study thoroughly assesses the impact of these rates on training dynamics (as evidenced by loss convergence), generalization performance (as measured by accuracy) and computational efficiency (as reflected in total training time) in the context of neural machine translation tasks. The findings not only provide robust scientific evidence for the principles that govern learning rate selection, but also highlight the importance of rigorous hyperparameter tuning for Transformer architectures. This research aims to provide practitioners with actionable insights to facilitate more effective model configuration and optimize deployment strategies in real-world sequence-to-sequence applications.

Related Work

In the original Transformer study (*Vaswani et al., 2017*), the authors employed the Adam optimizer alongside a custom learning rate schedule that included a linear warmup phase followed by inverse square root decay, highlighting the sensitivity of the architecture to learning

rate dynamics(Vaswani et al. 2017). More recent implementations, such as by *Yan and Shao (2024)*, adopt fixed initial learning rates (e.g., 1e-3 with AdamW), further emphasizing the ongoing interest in understanding the effects of learning rate settings on Transformer performance (Yan and Shao 2024) (Liu et al. 2020). Jurkiewicz et al. present top-performing systems for propaganda technique classification and span identification using semi-supervised learning. Their work highlights the novel use of RoBERTa-CRF for span identification and introduces Span CLS layers for classification, conducted with transformer-based language models and learning rates of 5e-4 and 2e-5 (Jurkiewicz et al. 2020). Huang et al. address optimization challenges in Transformers caused by unstable gradients that typically require learning rate warm-up. They propose a novel weight initialization method that stabilizes training, eliminating the need for warm-up even in very deep Transformer models (Huang et al. 2020). Liang et al. propose a training method that adjusts learning rates per parameter based on sensitivity to reduce redundancy in large Transformer models, improving parameter utilization and generalization across tasks. They select learning rates in the range of 2e-4, 3e-4, 8e-4, 1e-3, 5e-4, 7e-4 and 2e-3 (Liang et al. 2022). Karpov et al. improve retrosynthetic reaction prediction using Transformer models with various learning rate schedules and snapshot learning, a technique that averages weights at learning rate minima to effectively prevent overfitting and boost accuracy (Karpov, Godin, and Tetko 2019). Xiong et al. show that learning rate warm-up is crucial for Post-LN Transformers due to unstable gradients near the output. However, Pre-LN Transformers have stable gradients at initialization, allowing training without warm-up, reducing time and hyperparameter tuning (Xiong et al. 2020). Wortsman et al. address training instabilities in large Transformers by reproducing them at smaller scales, showing that issues such as logit growth and divergence can arise with high learning rates even in small models and that mitigation techniques like warm-up and weight decay remain effective across different model sizes (Wortsman et al. 2024). Shazeer and Stern propose reducing memory usage in adaptive optimizers by approximating per-parameter second moments through per-row and per-column sums. They also introduce update clipping and gradually increasing decay rates to prevent excessively large updates, achieving Transformer training performance comparable to Adam while using significantly less memory (Shazeer and Stern 2018). Li and Ke analyzed how varying dropout rates across layers and residual connections impact overfitting, training efficiency and generalization in language models, highlighting a key trade-off between residual depth and dropout for optimal performance. In their study using the Transformer architecture, the learning rate was initially set to 1e-3, with decay allowed down to a minimum of 1e-4 over 50,000 iterations(Li and Ke 2024). Lialin et al. introduce ReLoRA, a parameter-efficient training method that uses low-rank updates for large Transformer models, achieving comparable performance to standard training while reducing memory usage and accelerating training. They experimented with learning rates of 1e-3, 5e-4 and 4e-4(Lialin et al. 2024). Rothermel et al. show that the reported success of frozen pretrained Transformers in transfer tasks is due to insufficient learning rate tuning. By testing rates from 1e-2 to 1e-6, they find that fully fine-tuned models outperform or match training from scratch, highlighting the importance of proper learning rate selection in transfer learning. In contrast, in this study analyzes learning rates from 1e-3 to 1e-6 on Transformer language models, focusing on optimization stability and convergence. We find that high rates cause instability, low rates lead to underfitting and 1e-4 achieves the best balance for smooth convergence and generalization. Thus, while both works stress learning rate tuning, Rothermel et al. focus on transfer tasks and freezing, whereas ours focuses on training dynamics in language modeling (Rothermel et al. 2021). Wortsman et al. train small decoder-only Transformer models using an auto-regressive loss in a GPT-2-like setup, implemented with Flax and trained on the C4 dataset. They experiment with learning rate schedules—such as warm-up and cosine decay—

and apply regularization techniques including weight decay and z-loss. Their primary focus is on understanding training instabilities that emerge at high learning rates by analyzing the behavior of loss under various configurations. While both their work and mine involve loss analysis, my study diverges by analyzing the relationship between learning rate and model performance metrics (e.g., BLEU score and final loss) under stable training conditions. Additionally, focused on the interactions between learning rate and architectural hyperparameters such as embedding size and the number of attention heads, rather than the emergence of instability(Wortsman et al. 2024).

While existing literature has extensively analyzed dynamic learning rate schedules and advanced optimization techniques a systematic empirical analyz into the isolated effects of a comprehensive range of *fixed* learning rates on Transformer models across multiple key performance indicators remains less explored. In particular prior studies have highlighted optimal initial rates specific rates for niche tasks or parameter-specific adjustments. Challenges like unstable gradients have led to proposed solutions such as novel initializations or a focus on architectural specifics. Moreover, studies on training instabilities or the impact of learning rate in transfer learning with frozen layers often focus on specific contexts. In contrast, the present study offers a holistic analysis by systematically evaluating fixed learning rates across a broad spectrum (1e-2 to 1e-7) within Transformer models for neural machine translation. We meticulously assess their concurrent impact on training dynamics (including loss convergence and stability, notably addressing behaviors like the high non-converging loss at 1e-2), generalization performance (accuracy) and computational efficiency (total training time). This comprehensive approach provides an in-depth understanding of how fixed learning rate choices directly influence the multifaceted aspects of Transformer model training and deployment under standard conditions, thereby filling a critical gap in the existing literature.

Methodology

This section describes the setup and the specific hyperparameters configured for the Transformer model used in this study. Selecting these parameters is crucial for ensuring that results from different learning rate analysis is reproducible and comparable. Table 1 summarizes the core configuration, including architectural specifications and training parameters. As detailed in Table 1, the Transformer model architecture was standardized with an embedding dimension of 128, a feed-forward unit size of 128, 4 attention heads and 3 layers. A dropout rate of 0.1 was applied to mitigate overfitting. The Adam optimizer was utilized for training, with Gelu selected as the activation function and a batch size of 32 was consistently maintained. Positional encoding was set to 10000. Crucially, this study systematically investigates the impact of various fixed learning rates, specifically 1e-2, 1e-3, 1e-4, 1e-5, 1e-6 and 1e-7, allowing for a focused analysis of their individual effects on model performance and convergence.

Table 1. Model Hyperparameters and Values

Hiperparametreler	Complexity Model
Embedding Dimension	128
Feed Forward Units	128
Number of Heads	4
Number of Layers	3
Dropout Rate	0.1
Learning Rate	1e-2, 1e-3, 1e-4, 1e-5, 1e-6, 1e-7
Batch Size	32
Positional Encoding	10000
Optimizer	Adam
Activation Function	Gelu

This study used a dataset of 20,000 different Turkish-English sentence pairs as the base corpus for training a neural machine translation (NMT) model. Preparing this dataset was essential for providing consistent input to the Transformer architecture. Before being entered into the model, all input and target sequences underwent a standardized preprocessing step that included limiting all sequences to a maximum length of 28 tokens. This precise ensured consistent input dimensions, enabling efficient batch processing and stable training dynamics under all conditions. The resulting vocabulary size was 7,361 tokens for the English target language and 19,892 tokens for the German source vocabulary, reflecting the unique lexical scope of the processed corpus in each language.

The performance of the model was comprehensively evaluated using three critical metric sets: first training loss and validation loss, second training accuracy and validation accuracy and third total training time. Training and validation loss provided crucial insights into the model's learning dynamics and convergence behavior during the optimization process, directly indicating the effectiveness of the model in minimizing prediction errors. Subsequently, training and validation accuracy served to rigorously assess the model's overall learning progress and its critical generalization capabilities on previously unseen data. Finally, total training time was meticulously recorded to quantify the computational efficiency associated with each analyzed fixed learning rate across the experimental configurations. This integrated evaluation framework facilitated a thorough analysis of how varying fixed learning rates directly influenced the model's performance, its operational efficiency and its convergence characteristics.

In this study, a high-performance computing (HPC) system was employed to address the substantial computational demands of the research. The HPC system operates on Rocky Linux 8.5, which is derived from Red Hat 8.5 and is powered by AMD EPYC 7543 processors. It consists of eight compute nodes, each equipped with 64 cores and 1024 GB of memory, thereby facilitating efficient parallel processing. To enhance data transfer rates, the system is integrated with HDR InfiniBand technology, which provides a connectivity bandwidth of 200 Gbps. This robust infrastructure enables the execution of complex computations and the handling of large datasets essential for the study.

Results And Discussion

A systematic evaluation of learning rate impact on Transformer model training, with all other hyperparameters held constant (as detailed in Table 1), revealed distinct convergence patterns across four tested values (1e-3, 1e-4, 1e-5 and 1e-6) over 100 epochs, as depicted in Figure 1.

The provided graph illustrates the training and validation loss curves across 100 epochs for a deep learning model, evaluating the impact of different learning rates: 1e-3, 1e-4, 1e-5 and 1e-6. With a learning rate of 1e-3, the training and validation loss curves initially decline steeply, reflecting rapid learning. However, improvement soon stabilizes and both losses peak at comparatively high levels. Notably, the validation loss consistently exceeds the training loss throughout the epochs, suggesting suboptimal generalization. This behavior may indicate overfitting or instability in the optimization process. It could be caused by the learning rate being too high, which prevents the model from converging to a more optimal solution in the parameter space. In contrast, the learning rate of 1e-4 demonstrates a more favorable trend, exhibiting a rapid initial reduction in both training and validation losses, followed by a steady and consistent decline, with the validation loss closely tracking the training loss. This suggests stable learning and good generalization. The learning rate of 1e-5 also shows a consistent reduction in both losses, although at a slower speed than 1e-4. This indicates a cautious yet effective learning process. Finally, the 1e-6 learning rate results in a very slow and gradual decrease in both training and validation losses, with the curves remaining relatively high throughout the training epochs. This behavior is characteristic of underfitting, where the learning rate is too low to effectively update the model parameters and achieve optimal performanc. In general, the graph strongly suggests that learning rates of 1e-4 and 1e-5 provide the most effective balance for this model, achieving stable convergence and robust generalization.

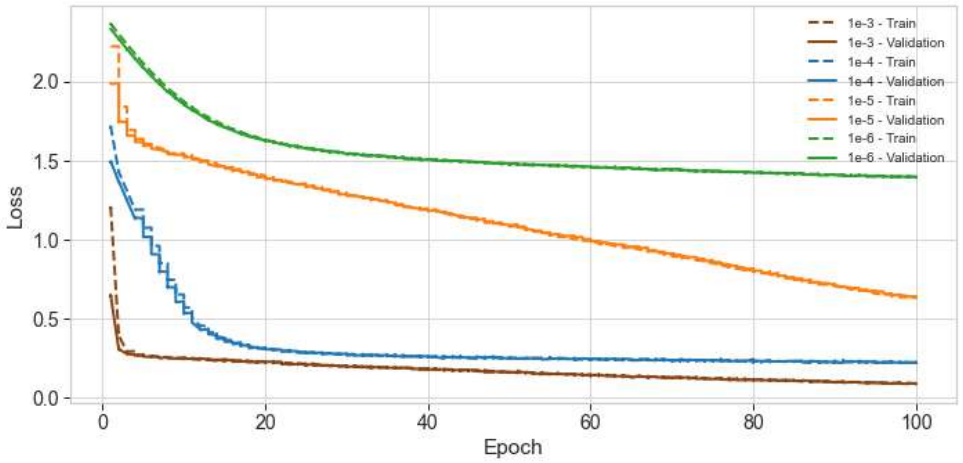


Figure 1: Training and validation loss curves for learning rate values of 1e-3, 1e-4, 1e-5 and 1e-6.

Figure 2 presents a comparative analysis of the training and validation loss trajectories across a range of learning rates. The inclusion of the extreme values 1e-2 and 1e-7 allows for a more comprehensive evaluation of convergence dynamics. At a learning rate of 1e-2, both the training and validation loss values are observed to remain persistently elevated throughout the entire training process. This clearly indicates a failure of the model to converge effectively.

This lack of convergence is primarily attributable to excessively large gradient updates, which impede the optimization algorithm from locating and settling into a stable minimum. Consequently, this specific learning rate configuration significantly hinders the model from achieving its potential performance. Conversely, at a learning rate of 1e-7, the loss curves exhibit minimal decline over epochs, suggesting a significantly slow learning process that limits the model's capacity to effectively minimize the objective function. These observations emphasize the critical role of learning rate selection in ensuring both stable convergence and optimal generalization, as inappropriate values can lead to underfitting or divergence.

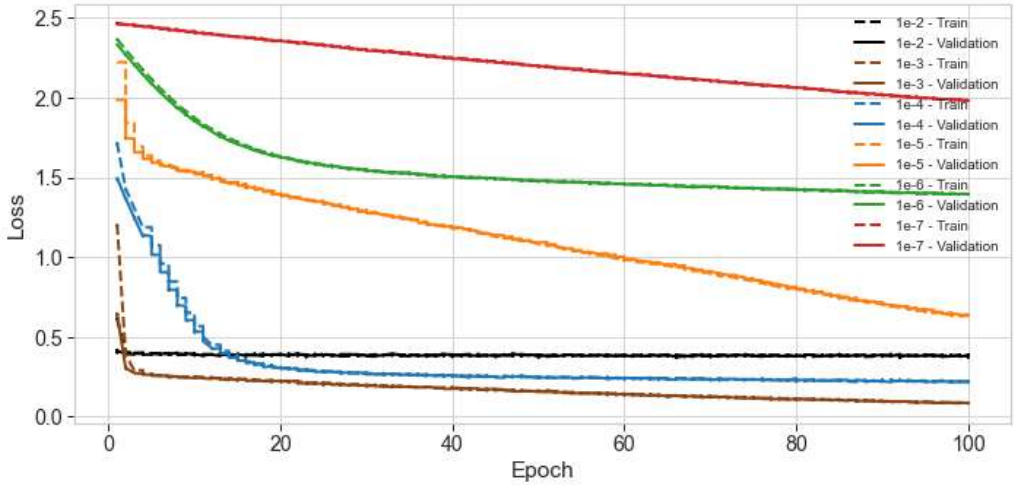


Figure 2: Training and validation loss curves for learning rate values of 1e-2, 1e-3, 1e-4, 1e-5, 1e-6 and 1e-7

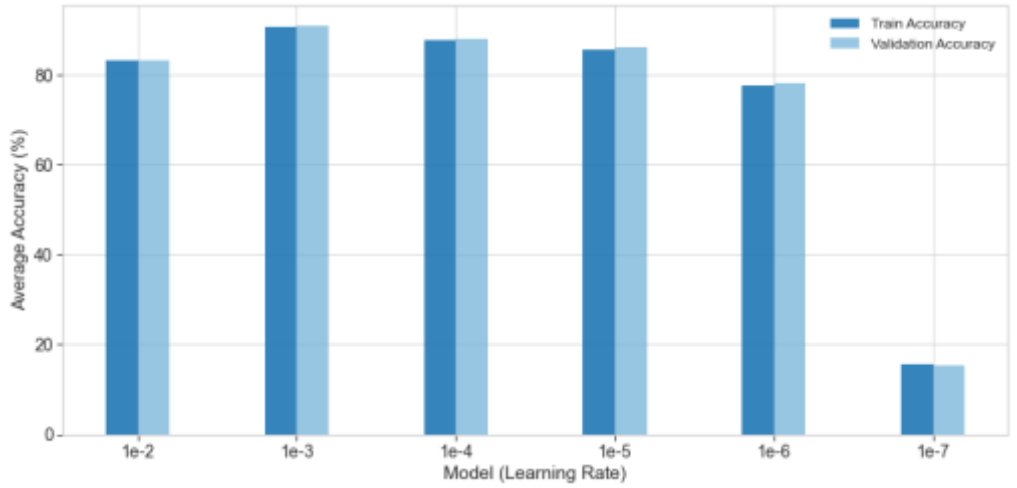


Figure 3: Impact of Learning Rates on Average Model Accuracy

Understanding the optimal configuration of hyperparameters is crucial for maximizing the performance and generalization capabilities of machine learning models. Figure 3 illustrates the relationship between various learning rates and the corresponding average training and validation accuracies of a model. As depicted, the model exhibits peak performance at a learning rate of 1e-3, achieving approximately 93% for both training and validation accuracy. Deviations from this optimal rate generally lead to a decline in accuracy. Specifically, as the

learning rate decreases beyond 1e-3 (e.g., from 1e-4 down to 1e-7), a progressive decline in accuracy is observed. This decline becomes sharp at learning rates of 1e-6 and particularly 1e-7, suggesting that the model struggles to converge effectively or learn meaningful patterns due to excessively small step sizes. Conversely, at a learning rate of 1e-2, the model still performs relatively well, although slightly below the 1e-3 optimum. Similarly, 1e-4 and 1e-5 also demonstrate strong performance, with only marginal decreases compared to the peak. This analysis underscores the critical importance of selecting an appropriate learning rate for optimal model performance and generalization capability, as an incorrectly chosen rate can severely hinder learning efficiency and final accuracy.

In addition to achieving optimal accuracy, the computational efficiency of machine learning models is critical to their practical deployment and scalability, especially when working with large datasets or real-time applications. Figure 4 illustrates the total computation time (in seconds) required by the model when operating with different learning rates. As shown in Figure 4, the model's execution time varies across the analyzed learning rates, indicating a relationship that is not simply linear. The most efficient execution, indicating the lowest total time, is achieved at a learning rate of 1e-5, where the model completes its operations in approximately 305 seconds. Conversely, the longest computation times are observed at the extreme ends of the tested range specifically, at a learning rate of 1e-7, the model takes approximately 355 seconds, representing the highest recorded time. Other learning rates, such as 1e-2, 1e-3, 1e-4 and 1e-6, fall within this range, indicating varying degrees of computational efficiency. This analysis suggests that selecting an optimal learning rate is not only crucial for model accuracy (as seen in Figure 3) but also plays a significant role in determining the computational cost and overall efficiency of the model's training or inference process.

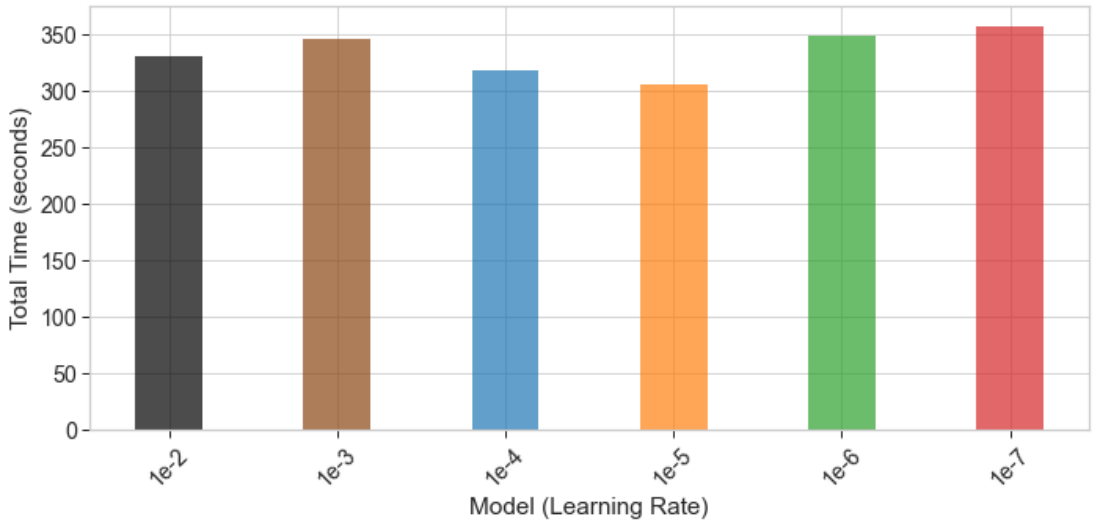


Figure 4: Total Time Taken by Model at Various Learning Rates

Conclusion

The findings of this study highlight the significant impact of the learning rate on the performance of a machine learning model in terms of accuracy, computational cost and convergence stability. Although the highest accuracy was achieved with a learning rate of 1e-3, this configuration did not provide optimal computational efficiency, which was observed

with a learning rate of 1e-5 instead. This discrepancy reveals a fundamental trade-off between achieving peak accuracy and maintaining computational efficiency, emphasizing that optimizing one aspect may compromise the other. Although learning rate of 1e-2 produced relatively competitive accuracy and faster computation than 1e-3; however, its consistently elevated loss values indicate unstable convergence behavior. Conversely, extremely low learning rates, such as 1e-7, resulted in substantially reduced accuracy and extended computation times, further illustrating the delicate balance required in learning rate selection. Therefore, selecting an appropriate learning rate is crucial not only for achieving optimal model performance but also for ensuring efficient and stable training dynamics. This study has shown that an optimum learning rate of 1e-4 strikes a balance between accuracy, training stability and computational efficiency.

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Conflicts of Interest

No conflict of interest was declared by the authors.

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DIELECTRIC PROPERTIES OF CADMIUM SULFIDE IN THE TERAHERTZ FREQUENCY BAND

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ABSTRACT

The terahertz (THz) frequency range, which spans from 0.1 to 10 THz, serves as a bridge between microwave and infrared radiation. This range holds transformative potential for applications in imaging, spectroscopy, sensing, and high-speed communication. However, the successful development of efficient THz technologies relies on advanced materials that can generate, modulate, and detect these waves. Cadmium sulfide (CdS), a II-VI compound semiconductor, has emerged as a promising candidate for THz applications due to its unique optoelectronic and structural properties. In this study, we examine the dielectric properties of CdS on a glass substrate using the powerful analytical technique known as THz time-domain spectroscopy (THz-TDS). We investigate how immersion time affects various properties, including the refractive index, permittivity, absorption coefficient, and loss tangent of CdS on glass. The results indicate that increasing the immersion time reduces both the absorption coefficient and the loss tangent of CdS on glass, while having no effect on the refractive index or permittivity. Moreover, advancements in material fabrication highlight CdS's potential to address critical gaps in THz technology. This study explores the fundamental properties of CdS in the THz frequency range and evaluates its potential for fully utilizing the terahertz spectrum. These properties enable CdS to perform exceptionally well in THz photoconductive switches.

Keywords: Terahertz, Cadmium sulfide, Dielectric properties, THz time-domain spectroscopy.

Introduction

The terahertz (THz) frequency range, typically defined between 0.1 and 10 THz, occupies a unique position in the electromagnetic spectrum situated between the microwave and infrared regions (Mollah et al., 2020). This intermediate spectral window has garnered increasing interest in recent years due to its distinctive interactions with matter and its broad applicability in various scientific and technological domains(Baxter & Guglietta, 2011). THz waves are non-ionizing, thereby posing minimal risk to biological tissues, and possess the capability to penetrate a variety of non-metallic and non-polar materials such as plastics, fabrics, and ceramics (Kundu & Pathak, 2024). These properties make the THz region particularly advantageous for non-destructive imaging, high-resolution spectroscopy, security screening, and next-generation wireless communication systems (Nsengiyumva et al., 2023). Beyond its functional uses, the THz domain holds significant promise for probing material properties at the microscopic and mesoscopic levels. Among the most powerful techniques available in this regime is terahertz time-domain spectroscopy (THz-TDS), which enables precise measurement of a material's complex dielectric response over a wide frequency range (Shekari et al., 2025). Unlike conventional optical techniques, THz-TDS directly provides both amplitude and phase information of transmitted or reflected THz pulses, allowing for accurate extraction of parameters such as refractive index, absorption coefficient, and permittivity. As such, it serves as a robust, non-invasive tool for the investigation of dielectric behavior in various functional materials. In this context, cadmium sulfide (CdS) emerges as a technologically relevant material warranting further investigation. CdS is a direct bandgap semiconductor belonging to the II–VI group, widely utilized in optoelectronic devices including solar cells, photodetectors, and thin-film transistors (Ismail et al., 2023). Its optical and electrical properties have been extensively studied in the visible and near-infrared regions; however, a comprehensive understanding of its dielectric response in the THz domain remains limited. Given the increasing interest in integrating THz technologies with existing semiconductor platforms, characterizing the THz dielectric behavior of CdS is both timely and essential. In this study, we aim to explore the dielectric properties of CdS thin films deposited on glass substrates using THz-TDS. The results provide insight into the frequency-dependent permittivity and absorption characteristics of CdS in the terahertz regime, contributing to the foundational knowledge necessary for future THz-integrated optoelectronic applications.

Materials and Methods

In this study, CdS thin films were fabricated using the Chemical Bath Deposition (CBD) technique, a widely used low-cost and low-temperature method that enables the controlled growth of semiconductor films on various substrates (De Guire et al., 2013). In this technique, glass substrates are immersed in a chemically reactive aqueous solution where the film forms through controlled precipitation and surface adsorption processes. To prepare the precursor solution, cadmium acetate and thiourea were dissolved in deionized water under continuous magnetic stirring. The concentrations of the precursors were adjusted to approximately 0.56 wt.% for cadmium acetate and 0.77 wt.% for thiourea. Subsequently, 20 mL of ammonium hydroxide was added dropwise to the solution in order to adjust the pH level and to form a clear, homogeneous complex solution. The mixture was then heated to 80 °C using a hot plate integrated with a magnetic stirrer to facilitate uniform mixing and controlled reaction kinetics. Prior to deposition, standard microscope glass slides were cleaned thoroughly using sequential ultrasonic baths of acetone, ethanol, and deionized water to ensure removal of surface contaminants. The cleaned substrates were then vertically immersed into the reaction solution, leaning slightly against the beaker wall to allow even exposure. The deposition process was

carried out for 15, 30, 45 and 60 minutes under constant temperature and stirring conditions (Figure 1). After the deposition, the substrates were removed from the chemical bath, rinsed gently yet thoroughly with deionized water to eliminate any loosely attached particles, and dried in ambient air. This procedure resulted in the formation of uniform, adherent CdS thin films on the glass substrates. The dielectric properties of the fabricated CdS films were characterized using THz-TDS, a powerful non-contact technique capable of probing both the amplitude and phase of ultrafast THz pulses transmitted through the sample. Measurements were performed using a TeraFlash Pro spectrometer, which operates based on the generation and detection of sub-picosecond terahertz pulses via a photoconductive antenna system. In this method, a broadband THz pulse is directed onto the sample, and the transmitted waveform is measured in the time domain. The recorded temporal signal is then subjected to Fourier transformation to obtain the frequency-dependent spectral response of the material. This technique enables direct extraction of both the real and imaginary parts of the complex refractive index, from which the absorption coefficient and dielectric permittivity are calculated. All measurements were conducted in a dry air environment to eliminate the influence of atmospheric water vapor absorption in the THz range. Reference measurements were taken using a bare glass substrate to ensure accurate extraction of the thin film's intrinsic response.



Figure 1. Cadmium sulfide (CdS) thin film samples grown for different durations.

Findings and Discussion

Figure 2 illustrates the frequency-dependent refractive index of CdS thin films deposited for varying immersion durations (15, 30, 45, and 60 minutes), as measured by THz-TDS.

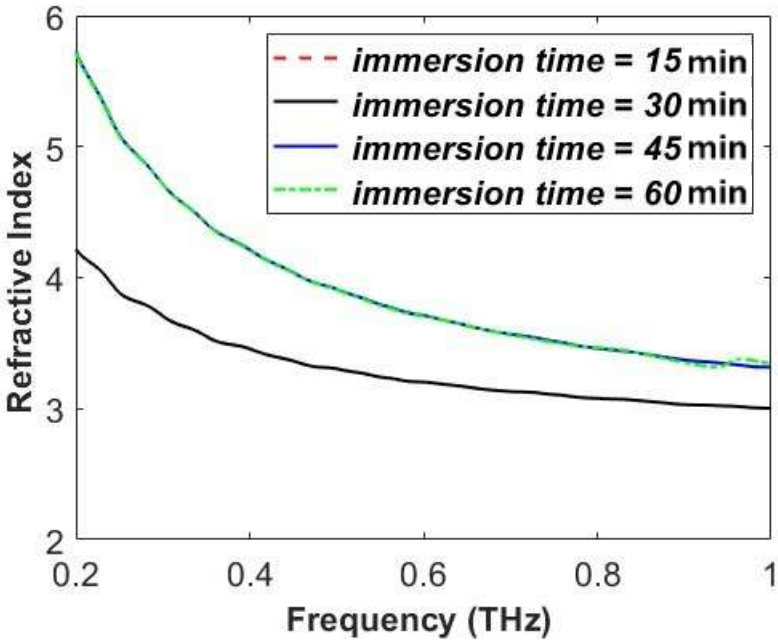


Figure 2. Refractive index spectra of CdS thin films for different immersion times (15, 30, 45, and 60 minutes).

As seen in Figure 2, all samples except the 30-minute immersion film exhibit similar refractive index profiles, starting from approximately 5.8 at 0.2 THz and gradually decreasing to about 3.2 at 1 THz, which is characteristic of typical dielectric dispersion behavior in the terahertz regime. The gradual decline in refractive index with increasing frequency is attributed to the frequency-dependent polarization response of the material, where dipolar and lattice vibrations contribute significantly in the lower THz range but diminish at higher frequencies. The sample with 30 minutes of immersion, however, consistently shows a lower refractive index across the entire frequency range compared to the other samples. This deviation suggests a noticeable difference in microstructural or morphological properties, potentially related to film density, grain boundaries, or void formation during growth. Since the refractive index is sensitive to material packing density and internal interfaces, a lower value indicates either reduced film compactness or increased porosity, which may arise from suboptimal nucleation and growth conditions at that specific deposition duration. In contrast, the near-complete overlap of the curves for 15, 45, and 60-minute immersions indicates that these films share a similar microstructural and optical behavior. This convergence implies that beyond 45 minutes, the growth process reaches a steady-state regime where film properties stabilize, and additional immersion time contributes minimally to further morphological refinement. The 15-minute sample's similarity with longer immersions suggests that even short deposition periods can yield films with mature microstructure under the current chemical bath conditions.

Figure 3 presents the absorption coefficient spectra of CdS thin films grown with varying immersion durations, measured in the THz frequency range using THz-TDS.

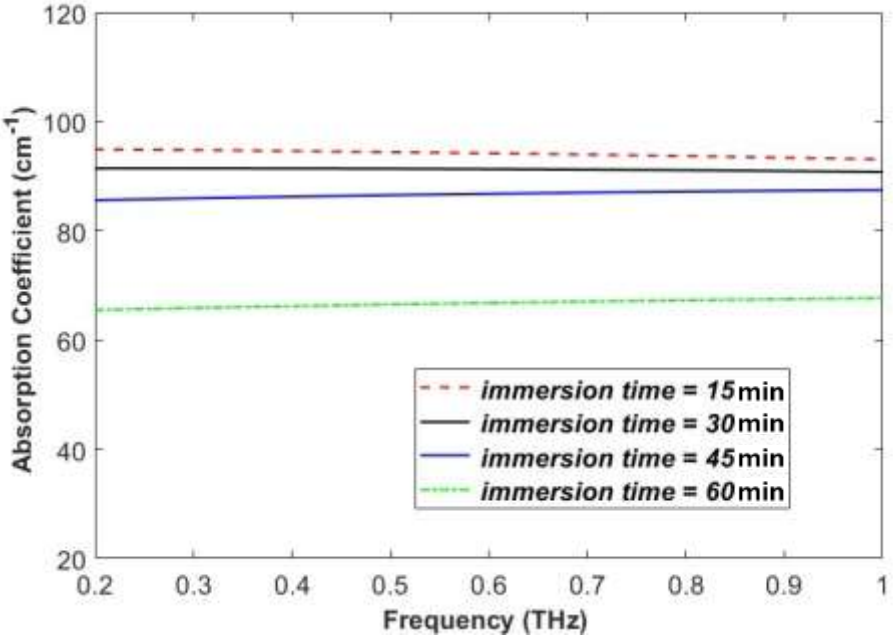


Figure 3. Absorption coefficient of CdS thin films as a function of frequency for different immersion times (15, 30, 45, and 60 minutes).

As shown in the figure, the absorption coefficient decreases with increasing immersion time. The 15-minute sample exhibits the highest absorption (~90 cm^{-1}), while the 60-minute sample shows the lowest (~65 cm^{-1}) across the entire frequency range. This trend suggests a progressive improvement in film uniformity, microstructural order, and reduction in defect-induced scattering with longer deposition durations. The significant drop in absorption for the longest immersion time indicates that extended growth leads to more compact and defect-free films, which absorb less THz radiation. In addition, all samples display a slight increase in absorption with frequency, reflecting a modest frequency-dependent behavior that is typical of many semiconducting materials in the THz domain. However, the slope of this increase is relatively low, suggesting that the CdS films maintain optical stability over the 0.2–1 THz range, a favorable property for THz applications. These results are also consistent with the refractive index trends discussed in Figure 1. Notably, the 30-minute sample, which exhibited the lowest refractive index, shows relatively high absorption, indicating potential microstructural inhomogeneity or incomplete crystallization. In contrast, the 60-minute film, with its low absorption and stable refractive index, demonstrates the best overall optical quality, suggesting a well-formed microstructure with minimal internal scattering centers.

Figure 4 presents the loss tangent ($\tan\delta$) spectra of CdS thin films deposited with different immersion durations (15, 30, 45, and 60 minutes), as a function of frequency in the 0.2–1 THz range.

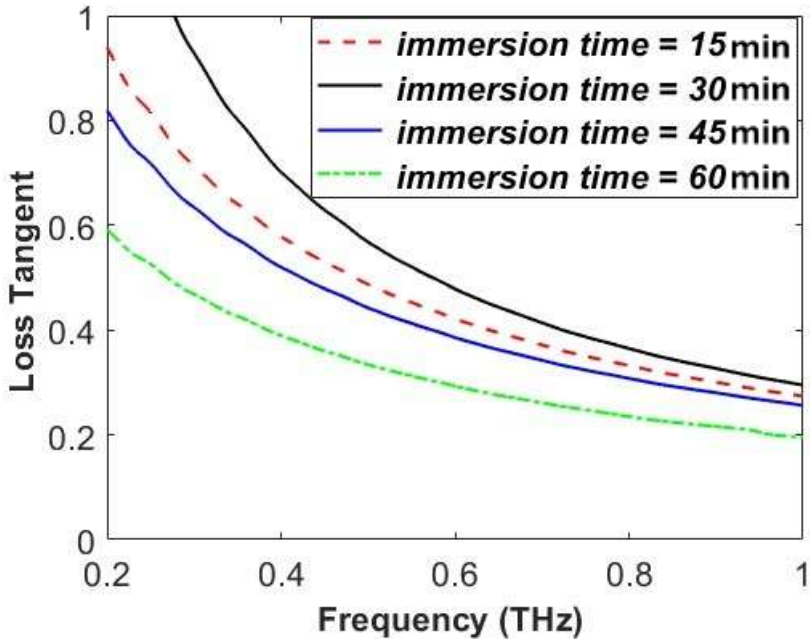


Figure 4. Loss tangent of CdS thin films on glass substrates for varying immersion times.

As shown in Figure 4, the loss tangent decreases significantly with increasing frequency for all samples. This trend indicates that dielectric losses in the CdS films diminish at higher THz frequencies, which is consistent with the expected behavior of many semiconductors due to reduced dipolar relaxation and phonon scattering effects at elevated frequencies. The effect of immersion time is clearly observed in the magnitude of the loss tangent. The 15-minute and 30-minute samples show the highest loss values across the frequency range, while the 45-minute and especially the 60-minute samples demonstrate considerably lower dielectric losses. This suggests that longer deposition times result in improved film microstructure, likely due to enhanced crystallinity, reduced defect density, and minimized grain boundary scattering. The 60-minute film, which exhibits the lowest loss tangent across the spectrum, stands out as the sample with the highest optical quality, reinforcing previous observations from the refractive index and absorption coefficient analyses. Additionally, the steep decline in loss tangent at lower frequencies and the gradual flattening at higher frequencies further emphasize the frequency-dependent nature of dielectric damping in CdS films. This behavior is beneficial for THz applications that operate in the upper portion of the spectrum, as the films maintain lower intrinsic energy dissipation. In summary, longer immersion times improve the dielectric performance of CdS thin films by simultaneously reducing absorption and dielectric loss.

Figure 5 shows the real dielectric permittivity spectra of CdS thin films grown with different immersion times, measured in the 0.2–1 THz frequency range.

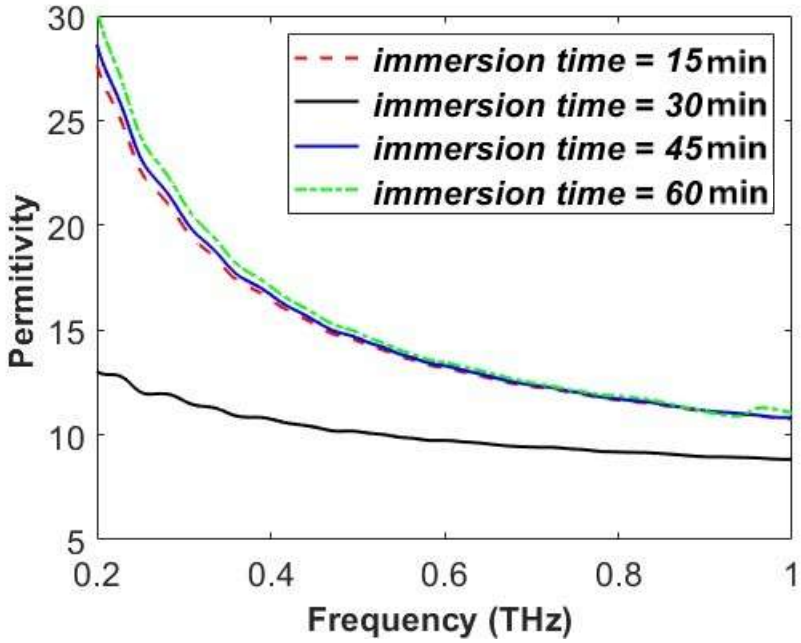


Figure 5. Frequency-dependent dielectric permittivity (ε') of CdS thin films for different immersion durations.

As shown in the graph, the permittivity of all CdS samples decreases sharply with increasing frequency. Starting from approximately 30 at around 0.2 THz, the values drop to ~11 near 1 THz. This indicates that CdS exhibits strong dielectric dispersion in the THz range. The decline is primarily attributed to the reduced contribution of polarizability at higher frequencies, as low-energy dipolar and lattice vibrational modes become less effective. The sample grown with a 30-minute immersion time displays noticeably lower permittivity values across the entire frequency spectrum. This suggests the presence of microstructural irregularities or a lower material density. The reduced polarizability in this sample implies that the growth conditions may not have supported the formation of a fully developed film. In contrast, the 15-, 45-, and 60-minute films exhibit closely overlapping curves, indicating similar microstructural and dielectric behavior. The convergence of these curves suggests that immersion beyond 45 minutes yields no significant improvement in permittivity. Moreover, the fact that even the 15-minute sample achieves sufficient polarizability highlights the effectiveness of the CBD method in rapidly initiating nucleation and early-stage growth. In conclusion, the permittivity of CdS films decreases strongly with frequency, a factor that must be carefully considered in THz optoelectronic applications.

Conclusion and Recommendations

This study demonstrates that the dielectric behavior of CdS thin films in the THz frequency range is strongly influenced by the immersion duration during chemical bath deposition. Extended immersion times lead to notably reduced absorption coefficients and loss tangents, indicating improved film quality and minimized dielectric losses. Across all samples, the optical parameters absorption, refractive index, permittivity, and loss tangent show a consistent decreasing trend with increasing frequency. These results reflect the characteristic dielectric dispersion of CdS in the THz regime. While significant differences are observed between samples at low frequencies, their optical responses tend to converge at higher frequencies,

suggesting that microstructural differences become less influential as the frequency increases. Among all samples, the 60-minute immersion condition produced films with the lowest absorption and dielectric loss, indicating improved homogeneity and reduced defect density. Conversely, the 15-minute sample exhibited higher absorption and permittivity at lower frequencies, likely due to incomplete growth, surface roughness, or residual moisture effects. These findings underscore the critical role of immersion time in governing the dielectric properties of CdS films. The data suggest that structural features such as film density, uniformity, and surface quality which are closely tied to deposition duration significantly affect how CdS interacts with THz radiation.

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DESIGN AND CHARACTERIZATION OF ANTIRESONANT NEGATIVE CURVATURE WAVEGUIDES FOR TERAHERTZ APPLICATIONS

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ABSTRACT

The terahertz (THz) frequency band offers significant opportunities for various critical applications such as high-resolution imaging, non-destructive testing, security screening, and wireless communication systems. However, appropriate waveguide technologies for the efficient utilization of this spectrum remain limited. Developing waveguides that operate effectively in this frequency range necessitates the use of air-core, polymer-based fiber structures as an alternative to conventional metallic designs. In this context, air-core polymer waveguides with negative curvature provide an innovative solution to reduce transmission losses while enabling broadband operation. Thus, this study focuses on designing, fabricating, and characterizing anti-resonant negative curvature waveguides that enable low-loss transmission in the 0.2 THz frequency range. Within the scope of this work, suitable polymer materials compatible with stereolithography-based 3D printers (SLA) were selected, and waveguide geometries were optimized using COMSOL simulations. The fabricated prototypes were characterized in terms of their optical and dielectric properties using Terahertz Time-Domain Spectroscopy (THz-TDS). The proposed structures offer an ideal platform for single-mode, low-loss transmission in the THz band, with broad bandwidth and fundamental mode propagation capabilities. This research presents a significant contribution to the development of innovative THz solutions in the fields of defense, security, and communication, aiming to enhance national expertise and capacity in THz technologies.

Keywords: SLA Fabrication, THz-TDS Characterization, Negative Curvature Fiber, THz Waveguide

Introduction

In recent years, considerable advancements have been achieved in the generation and detection of electromagnetic waves in the terahertz (THz) frequency range, typically defined between 0.1 and 10 THz (Pawar et al., 2013). For a long time, this region was known as the "terahertz gap" due to the lack of reliable sources and sensitive detectors (Zhang et al., 2019). However, since the mid-1980s, rapid progress in optoelectronic and photonic device technologies has significantly increased scientific and industrial interest in this spectral domain. Positioned between the infrared and microwave bands of the electromagnetic spectrum, terahertz waves exhibit properties of both regions, which enables their integration into hybrid systems for signal manipulation and transmission. As a result, THz waves have become increasingly important in the development of advanced functional components, including waveguides, filters, lenses, and polarizers(Mollah et al., 2020). One of the key advantages of THz radiation is its ability to penetrate many non-metallic, non-polar, and low-loss dielectric materials. This feature opens up numerous possibilities for applications in imaging, sensing, and spectroscopy (Rahaman et al., 2021). The relatively short wavelengths of terahertz waves, compared to microwave radiation, offer higher spatial resolution, making them particularly suitable for high-precision systems used in biomedical diagnostics, security screening, and non-destructive testing. Additionally, since THz radiation is non-ionizing, it can safely interact with biological tissues without inducing structural damage. Moreover, the THz spectrum contains unique absorption features corresponding to the vibrational and rotational modes of a variety of molecules, making it highly effective for chemical and biological identification (Zhao et al., 2014). Beyond these applications, growing interest in terahertz technology has also been observed in areas such as radio astronomy and high-speed wireless communications. To ensure efficient THz wave propagation, the development of specialized waveguide systems is essential. Although metallic waveguides have been used historically, their performance is significantly compromised at terahertz frequencies due to high conductive losses (Blanco-Redondo & Hudson, 2024). As a result, researchers have turned to alternative guiding structures based on dielectric and polymeric materials, which provide lower intrinsic absorption and greater design flexibility. Optical fibers fabricated from polymers, in particular, are of interest due to their low-loss characteristics in the terahertz regime and compatibility with various fabrication techniques. In this context, innovative waveguide geometries have emerged, including hollow-core and microstructured fiber designs (Wei et al., 2017). These configurations aim to reduce propagation losses by confining the electromagnetic field within low-loss regions, such as air-filled cores, rather than lossy solid materials. Hollow-core waveguides offer a significant advantage by enabling the confinement of THz radiation primarily within an air-filled central region, thereby mitigating the absorption losses typically associated with dielectric or polymeric core materials. To achieve this, the waveguide's internal structure must be carefully engineered to maintain mode confinement while preventing signal leakage (Wei et al., 2017). Among the various guiding mechanisms, photonic bandgap structures utilize periodic arrangements around the core to restrict wave propagation to specific frequency bands. While effective within narrow spectral windows, their limited bandwidth often restricts their utility in broadband applications. In contrast, antiresonant hollow-core waveguides have demonstrated superior performance over broader frequency ranges. These waveguides rely on the antiresonance effect of the surrounding cladding layers to reflect light back into the hollow core, thus minimizing leakage and material absorption (Ni et al., 2021). A particularly promising subclass of these structures involves negative-curvature geometries, where the inner surfaces of the cladding bend inward toward the core. This specific curvature reduces the interaction between the guided mode and the lossy material boundaries, thereby enhancing single-mode guidance and suppressing higher-order

modes. As a result, these waveguides are capable of delivering low-loss, high-fidelity transmission in the terahertz band, which is essential for high-capacity data links and sensitive spectroscopic measurements. The realization of such complex fiber architectures has been greatly facilitated by the emergence of advanced additive manufacturing techniques. Among these, stereolithography (SLA) has gained particular attention due to its ability to produce high-resolution, intricate structures using UV-curable photopolymers (Biswas et al., 2024). SLA enables the fabrication of smooth-surfaced, geometrically precise components that are critical for reducing scattering and ensuring optimal optical performance. Its layer-by-layer approach also allows for rapid prototyping and iterative design refinement, which is essential in experimental THz waveguide development. The availability of low-loss resin formulations further supports the use of SLA in constructing functional THz transmission components. To achieve optimal performance, the geometric design of antiresonant negative-curvature waveguides must be carefully tailored. These waveguides offer not only broadband and low-loss transmission but also stable single-mode propagation, which is critical for maintaining signal integrity. In conventional multimode systems, energy is distributed across multiple modes, leading to modal dispersion and reduced efficiency. By contrast, the inherent structure of negative-curvature fibers suppresses the excitation of higher-order modes and favors the propagation of the fundamental mode, resulting in enhanced energy confinement and transmission stability(Mu et al., 2024). Given their favorable characteristics, antiresonant negative-curvature waveguides are emerging as a key enabling technology for terahertz applications. Their potential extends beyond laboratory-scale demonstrations to practical use in biomedical imaging, remote sensing, spectroscopy, and next-generation communication systems. Furthermore, their ability to support high-speed, broadband data transmission while maintaining low attenuation makes them particularly well suited for integration into compact and efficient THz platforms (Yu, 2021). In the context of security and defense, these waveguides offer enhanced detection capabilities through high-resolution imaging and precise spectral recognition, enabling the identification of concealed threats and hazardous materials. In summary, the development of antiresonant negative-curvature waveguides addresses many of the key challenges associated with terahertz signal transmission. By combining broadband operation, low-loss performance, and modal selectivity, these advanced fiber structures offer a compelling solution for expanding the capabilities of THz technologies. Their implementation promises not only to enhance the performance of current systems but also to unlock new opportunities across scientific, industrial, and defense-related domains.

Materials and Methods

In this study, negative curvature hollow-core fiber structures were initially designed and analyzed using the COMSOL Multiphysics simulation environment. The geometric parameters of the fiber structures were defined based on functional considerations to support low-loss terahertz wave guidance. The first fiber configuration consists of two concentric rings with the following dimensional specifications: an outer ring diameter of 30 mm, outer wall thickness of 2 mm, an inner ring diameter of 6 mm, and an inner wall thickness of 0.5 mm. The central air core, which enables low-index guidance, was designed with a diameter of 14 mm. A second configuration was also developed, incorporating four inner rings to evaluate the effect of structural complexity on modal confinement and propagation characteristics. Following the completion of numerical simulations, the optimized structures were fabricated using a Formlabs 3L SLA 3D printer. Two commercial photopolymer resins “High Clear V4 and Rigid 10K” were used in the fabrication process to compare the optical quality and mechanical stability of the

final components. All waveguide samples were produced with a fixed height of 5 cm. After fabrication, the experimental characterization of the THz transmission properties was carried out using a TeraFlash Pro terahertz THz-TDS system. The measurement setup enabled the extraction of frequency-dependent refractive index profiles, which were used to assess the waveguiding performance and material dispersion characteristics of the fabricated fiber structures.

Findings and Discussion

COMSOL Multiphysics simulations effectively demonstrated the fundamental mode guidance characteristics and electric field distribution within the designed negative-curvature hollow-core fiber (NCHCF) structures. The simulation results revealed strong confinement of the electric field within the central hollow core, while the field intensity near the surrounding cladding walls remained minimal. This distribution confirms that antiresonant conditions are satisfied and that electromagnetic energy is efficiently confined within the core region. In the initial design, which features two concentric tubes, the mode tends to spread more in the horizontal direction, resulting in asymmetric field distribution and directional propagation. In contrast, the second design, incorporating four internal tubes, exhibits a symmetric field profile centered in the hollow core, enabling more stable and low-loss transmission. This symmetric confinement leads to improved mode stability and uniform propagation, making the four-tube configuration superior in terms of modal balance and optical guidance performance.

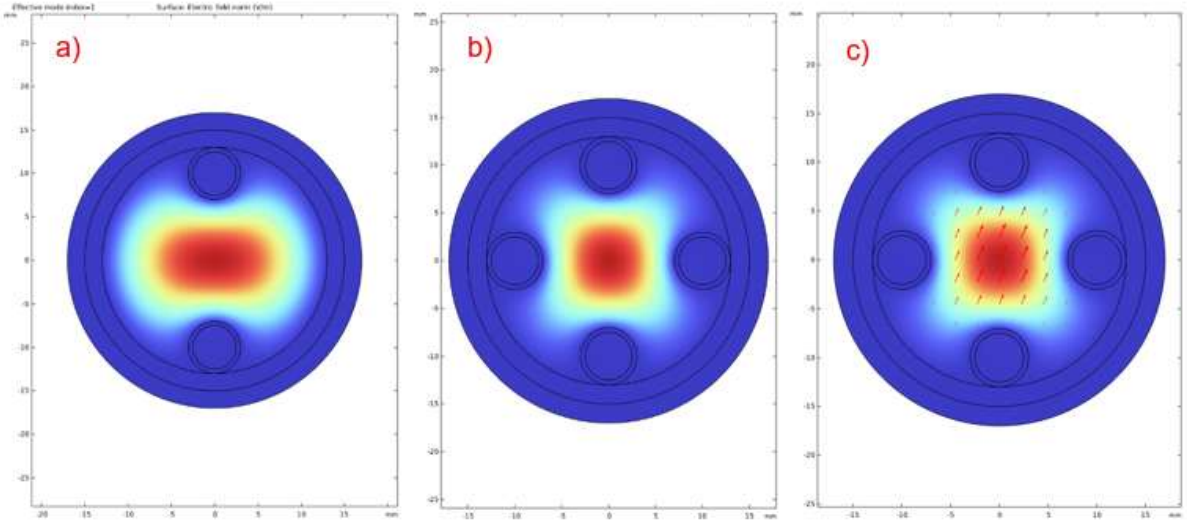


Figure 1. Electric field distributions of the fundamental mode obtained from COMSOL Multiphysics simulations for negative-curvature hollow-core waveguides. (a) Two-tube structure exhibiting horizontal mode spreading with asymmetrical confinement. (b) Four-tube structure showing symmetric mode confinement within the central air core. (c) Vector plot overlay of the electric field for the four-tube design, confirming stable and centralized mode propagation.

Based on these COMSOL findings, the experimental characterization phase focused on the four-tube fiber geometry. THz-TDS was employed to investigate the frequency-dependent optical behavior of the fabricated structures. Initially, a free-space (air) reference signal was recorded. Subsequently, the 3D-printed antiresonant negative-curvature waveguides produced

using Rigid 10K and Clear V4 resins were positioned between two parabolic-mirror antennas, and transmission measurements were repeated. The time-domain signals were subjected to Fourier transform to extract both amplitude and phase information in the frequency domain. Using these data, the complex transmission function was obtained, and frequency-dependent refractive index profiles were calculated for both resin types.

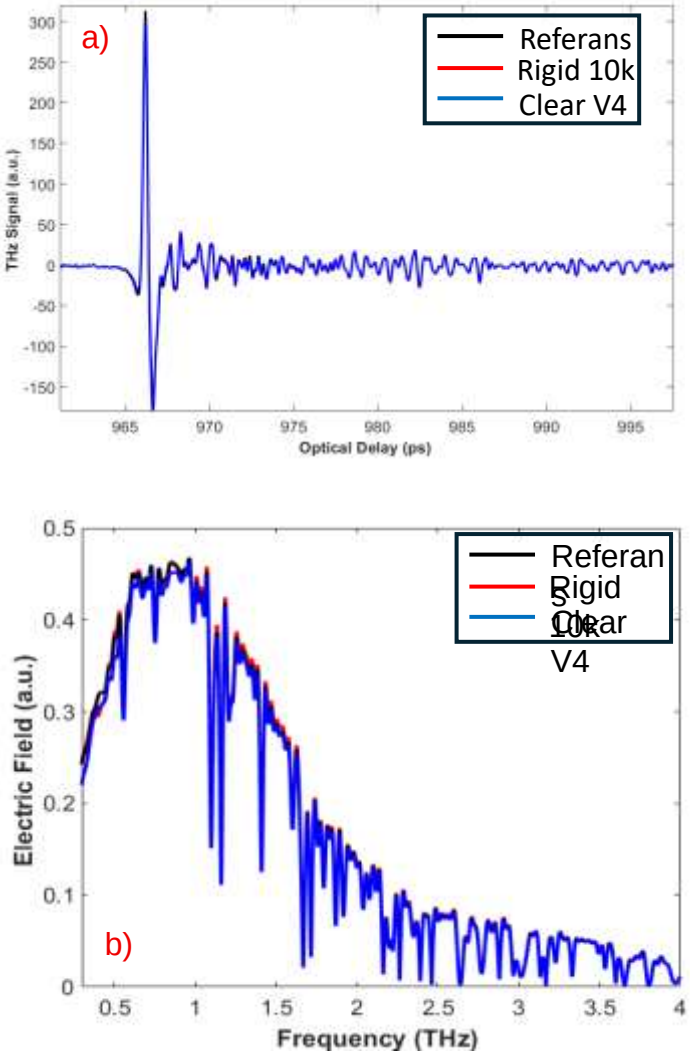


Figure 2. THz-TDS measurement results for antiresonant negative-curvature waveguides fabricated with Rigid 10K and Clear V4 resins. (a) Time-domain THz signal comparison showing the reference (air) signal and signals transmitted through the waveguides. (b) Corresponding frequency-domain spectra obtained via Fourier transformation, indicating the amplitude response over the 0.1–4 THz range.

The extracted refractive index profiles indicate that both fiber structures operate within a low-index environment close to $n \approx 1$ across the terahertz spectrum. This result clearly demonstrates that the antiresonant negative-curvature geometry effectively supports broadband, low-loss THz light propagation. Notably, the waveguide fabricated with Rigid 10K exhibited higher refractive index values and a more consistent spectral response across the frequency range, while Clear V4 showed slightly lower index values. These differences may be attributed to variations in material composition and the dispersive behavior of the polymer matrix in the THz

regime. Both time-domain attenuation and frequency-domain amplitude spectra support the conclusion that both resins are suitable for THz wave transmission, with Rigid 10K offering improved stability and spectral uniformity.

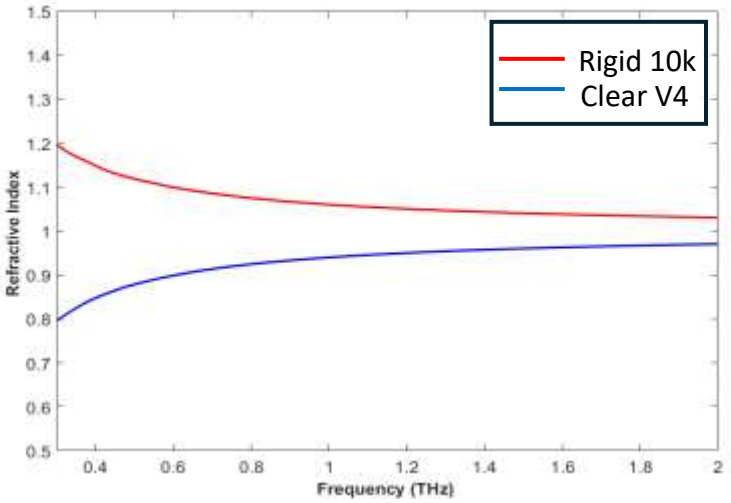


Figure 3. Frequency-dependent refractive index profiles of the 3D-printed antiresonant negative-curvature waveguides fabricated using Rigid 10K and Clear V4 resins.

In summary, the combined numerical and experimental results confirm that the four-tube negative-curvature antiresonant waveguide design provides an optimal platform for low-loss and single-mode terahertz transmission. Owing to its ability to minimize material interaction and maintain stable modal confinement, this structure holds significant promise for high-resolution, broadband, and low-attenuation THz applications.

Conclusion and Recommendations

In this study, antiresonant waveguides with negative curvature were designed, simulated, and experimentally evaluated for efficient THz wave transmission. Numerical analyses performed in the COMSOL Multiphysics environment revealed that the proposed structures are capable of supporting fundamental mode propagation while maintaining strong field confinement within the central hollow core. Among the different geometries investigated, the four-tube configuration demonstrated superior performance by providing a symmetric mode distribution and minimizing interaction with the lossy cladding material. Based on these simulation results, the four-tube structure was selected for experimental validation. Samples were fabricated using SLA with two distinct photopolymer resins: Rigid 10K and Clear V4. Subsequent terahertz tTHz-TDS measurements confirmed that both materials support low-loss THz wave transmission within the designed waveguide structure. The refractive index values obtained from the frequency-domain analysis remained close to unity, which is consistent with the expected behavior of air-core antiresonant fibers. The combined results of simulation and experimentation clearly demonstrate that the four-tube antiresonant negative-curvature waveguide design offers a promising platform for broadband, single-mode terahertz transmission. Its geometrical advantages, coupled with the versatility of SLA-based fabrication, make it a strong candidate for future applications in THz imaging, sensing, and communication systems

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A STUDY OF THE EFFECT OF INPUT POWER ON RESISTOJET PERFORMANCE

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ABSTRACT

Low power resistojet thrusters are a type of electrothermal propulsion systems which are capable of producing a thrust up to 100 mN at power less than 50 W, specific impulse up to 100 s, feed pressure up to 10 bar, and operating temperature up to 800K using most compressed or liquified-gases as propellant. Currently, concerning the growing interest in smaller satellites, low-power systems are of great interest as they can offer many advantages compared to other potential systems of the same category. However, the performance of such a system is highly dependent on the input power to the system and investigation of this dependency is of great concern. Therefore, a parametric study has been conducted to investigate the effect of input power on the thruster performance. This study evaluates the performance of a resistojet thruster using Computational Fluid Dynamics (CFD) simulations across varying input electrical powers (0-10-20-30 W) and propellant gas butane (C_4H_{10}). The simulations assess key performance parameters such as thrust, specific impulse (I_{sp}), and mass flow rate under different operational conditions. The results demonstrate the influence of propellant thermophysical properties and input power on thruster efficiency. The findings provide insights into optimal power settings for resistojet thrusters in space propulsion applications, supporting future design and mission-specific performance optimization.The results of the present study showed that increasing the power from 0 to 30 W, accelerates the exhaust velocity from 641.62to 661.92 m/s while mass flow diminishes from 145.04 mg/s to 140.86 mg/s. Thrust proved to be independent of input power while the specific impulse, which is supposed to increase directly with square root of flow temperature, improved from 68.251 to 70.442 s.

Keywords: Resistojet, Electric Propulsion, CFD, Control Thruster, Small Satellite, Outer Space.

Introduction

In recent years, the increasing demand for small and cost-effective space missions has led to significant interest in compact, low-power propulsion systems. Among various options, resistojet thrusters—electrothermal propulsion devices—have gained attention due to their ability to provide efficient and reliable performance within the constraints of small spacecraft, where power limitations and mass efficiency are critical. These thrusters are capable of producing thrusts up to 100 mN at power levels below 50 W, with a specific impulse (I_{sp}) up to 100 s, making them suitable for a wide range of small satellite applications [1].

Resistojets operate by heating a propellant using electrical power to produce a high-temperature gas, which is then expelled through a nozzle to generate thrust. The performance of these systems is closely linked to the thermophysical properties of the chosen propellant and the amount of input power provided to the system. As such, a comprehensive understanding of how different operational parameters—particularly input power and propellant type—affect the thruster's performance is essential for optimizing design and operational efficiency in space missions [2][3].

Recent studies have explored various factors affecting the performance of resistojet thrusters, including the impact of input power, propellant selection, and nozzle design. For example, Krejci and Lozano [4] investigated the performance of electrothermal thrusters using hydrogen and xenon as propellants, revealing that hydrogen provides better specific impulse due to its lower molecular weight. Similarly, Miele et al. [5] examined the influence of different propellants on the efficiency of low-power resistojet thrusters, emphasizing the role of thermal properties in optimizing system performance.

The relationship between power input and system performance is complex. Increasing input power typically results in higher exhaust velocities and improved specific impulse, but the effect on mass flow and thrust requires careful consideration. By analyzing the performance of different input powers under a range of operating conditions, this work aims to contribute to the optimization of resistojet thrusters for future space propulsion applications, providing a basis for informed power management in spacecraft design [6].

Materials and Method

The present study employs CFD simulations to investigate the performance of a low power resistojet thruster using butane (C_4H_{10}) as a propellant. All computations were carried out in ANSYS Fluent 2023 R2 under steady, compressible flow assumptions. The computational domain, shown in Figure 1, consists of a 10 mm diameter inlet section, a 50 mm long heated channel, a 0.5 mm throat, and a 7 mm diameter divergent nozzle with a 30° expansion angle.

The simulations were performed using the Reynolds-Averaged Navier-Stokes (RANS) equations with the k-ω SST turbulence model, which is well-suited for capturing near-wall viscous effects and flow separation in small-scale nozzles. The energy equation was enabled to account for heat transfer, and the ideal gas law was applied for butane (C_4H_{10}) to model compressibility effects.

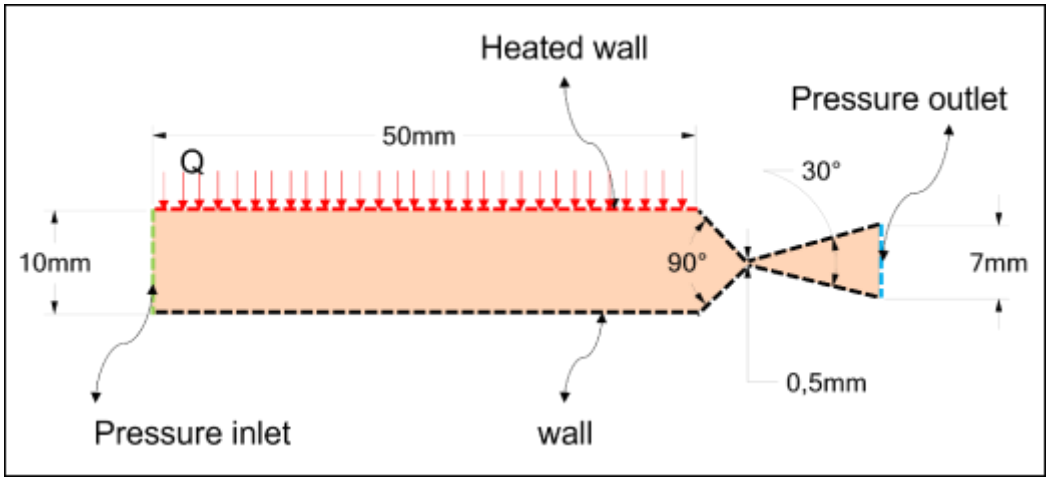


Figure 1. Calculation Domain

Boundary conditions implemented in the computational model are summarized in Table 1 and Figure 1. A constant pressure inlet condition of 2.5 bar was specified at the thruster inlet, representing the propellant supply. The heated wall, corresponding to the heating chamber, received uniform heat flux input of 0, 10, 20, and 30 W to investigate the influence of input power variations. A no-slip boundary condition was applied to all solid walls. At the nozzle exit, a fixed low-pressure outlet boundary of 50 Pa was assigned, representing conditions typical of outer space vacuum environments.

Table 1. Boundary Conditions

Boundary	Conditions
Pressure inlet	2.5 bar
Heated wall	0-10-20-30 W
Wall	No-slip condition
Pressure outlet	50 pa

A 2D axisymmetric mesh was created in ANSYS Meshing comprising 26 004 cells and 26 508 nodes. A structured grid with 30 prism layers was applied along all walls, with a first-layer thickness of 1.4×10^{-7} m and a growth rate of 1.20. Mesh structure is presented in Figure 2 and mesh properties presented in table 2.

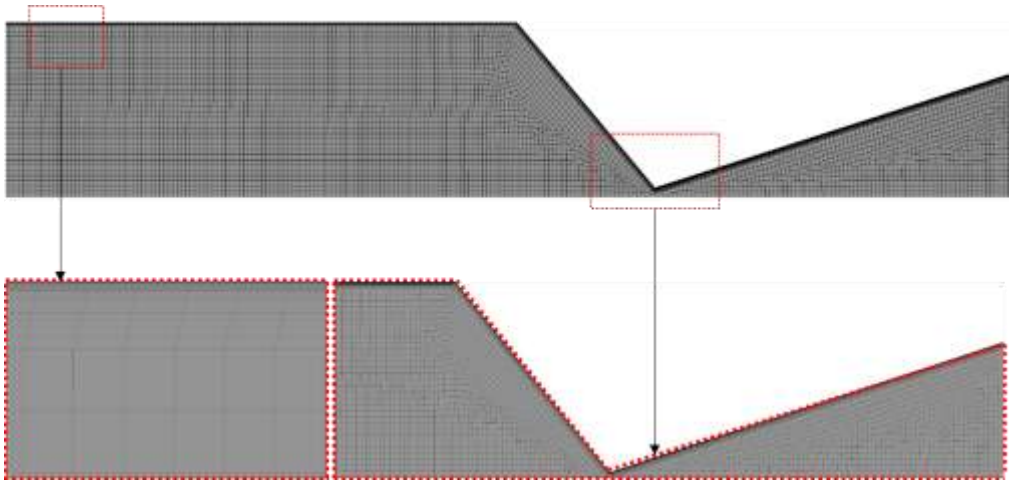


Figure 2. Mesh Structure

Table 2. Mesh Properties

Property	**Value**
Node Number	26 508
Cell Number	26 004
First Layer Height	$1{,}4\times10^{-7}$ m
Layer number	30
Growth Rate	1,20

Results and Discussion

Figure 3 presents the total pressure contours within the resistojet thruster for different input powers (0, 10, 20, and 30 W). As illustrated, the pressure distribution remains nearly constant across the investigated power levels, primarily governed by the fixed inlet pressure boundary condition. This demonstrates that within the range studied, the influence of input power on pressure is minimal. However, the pressure drop at the nozzle throat remains prominent across all cases, underscoring that the main role of varying input power is related to thermal energy addition rather than altering the pressure conditions within the thruster significantly.

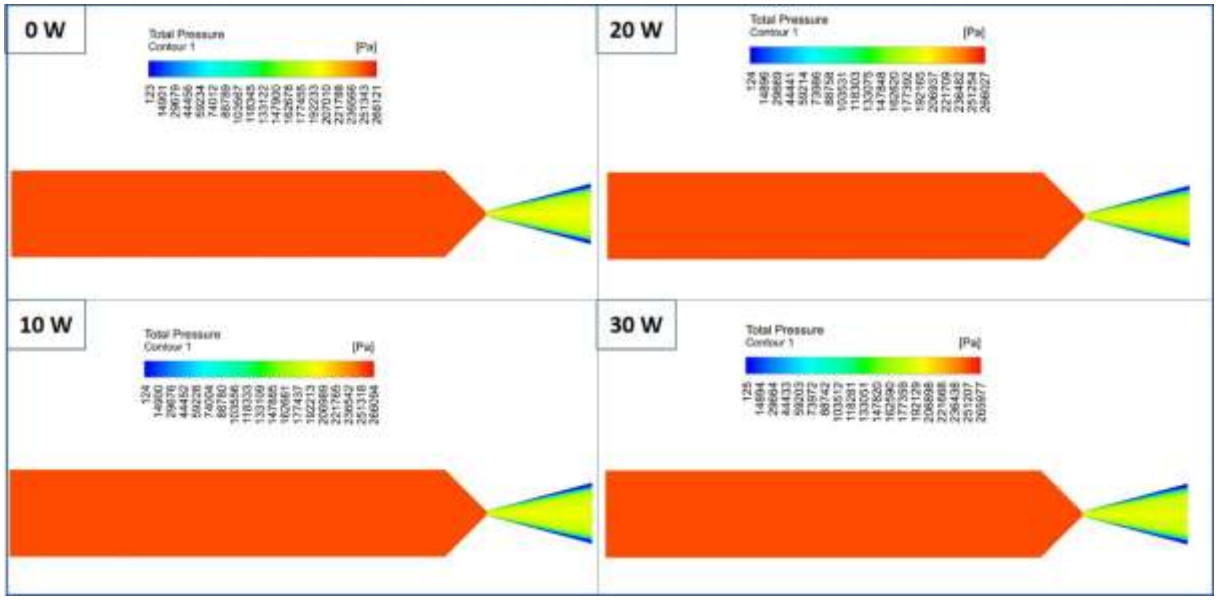


Figure 3. Input Power vs Total Pressure

Figure 4 shows total temperature contours within the resistojet thruster for different input power conditions (0, 10, 20, and 30 W). At 0 W, the thruster demonstrates uniform but relatively low temperatures throughout the domain, reflecting the absence of additional heating. With increasing input power (10 W and above), a clear thermal gradient emerges, indicating efficient heat transfer from the heated wall to the propellant gas. Particularly at 30 W, the maximum temperature reaches approximately 380 K, significantly enhancing the internal energy of the propellant.

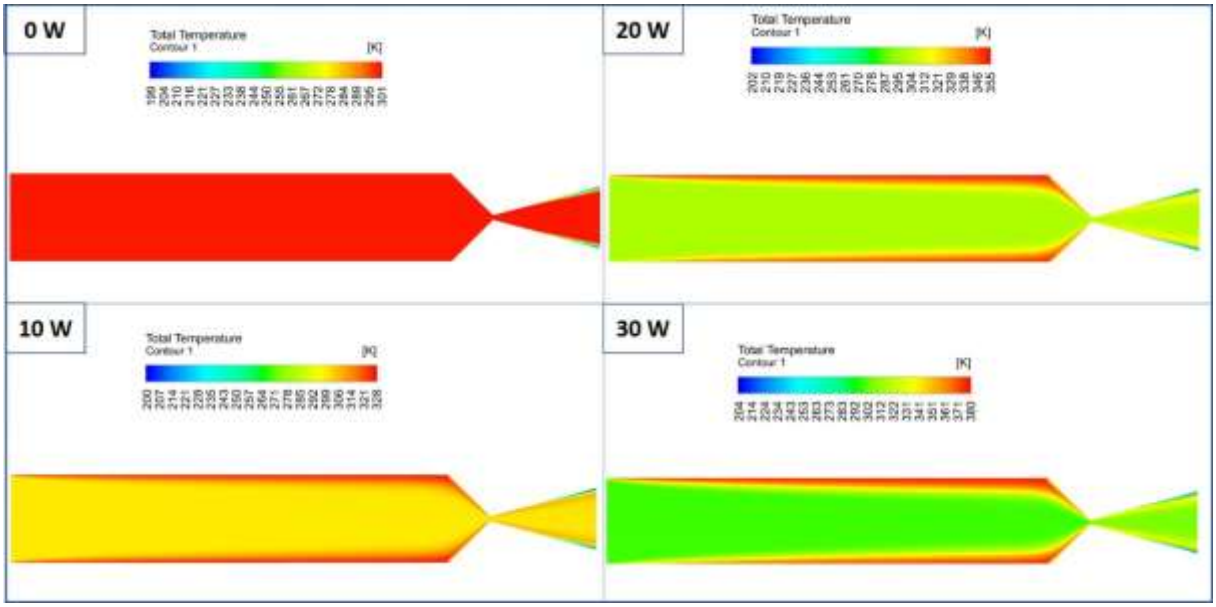


Figure 4. Input Power vs Total Temperature

Figure 5 presents the velocity contours within the resistojet thruster for input powers of 0, 10, 20, and 30 W. The results clearly illustrate the impact of power input on exhaust velocity. With no power (0 W), the exit velocity remains relatively low, approximately 673 m/s. Increasing the input power gradually enhances the thermal energy imparted to the propellant, thereby accelerating the flow through the nozzle. At the highest input power (30 W), the maximum velocity reaches approximately 700 m/s, confirming the direct influence of heating on the kinetic energy of the propellant gas.

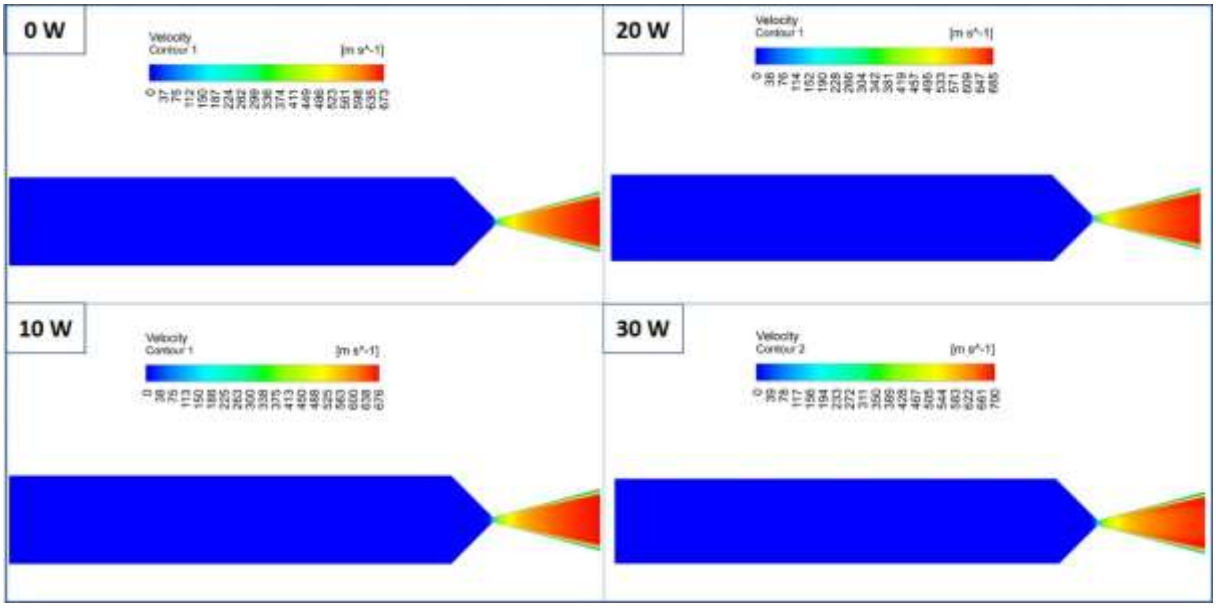


Figure 5. Input Power vs Velocity

Conclusions and Recommendations

Figures 6 and 7 clearly illustrate the relationship between input power and the primary performance parameters of the resistojet thruster. Figure 6 demonstrates that the specific impulse significantly increases as the input power rises from 0 W to 30 W. This improvement occurs due to enhanced heating of the propellant gas, resulting in increased thermal and kinetic energies within the nozzle and consequently higher exhaust velocities. The specific impulse increased from 68.251 s at 0 W to about 70.442 s at 30 W, indicating that the efficiency of the propulsion system substantially benefits from additional thermal energy input.

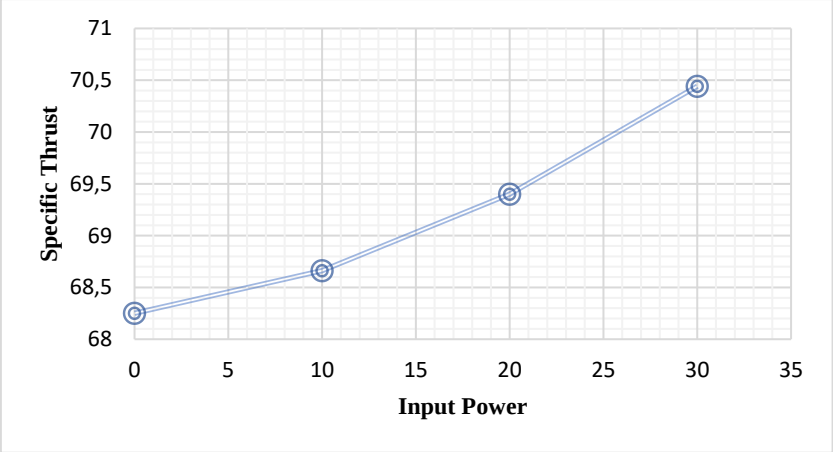


Figure 6. Input Power vs Specific Thrust

On the other hand, Figure 7 illustrates that the thrust produced by the resistojet remains relatively stable across the examined power levels. The minor variations observed—from 0.09711 N at 0 W to 0.09734 N at 30 W—indicate that, within this range of input power, the thrust is relatively independent of heating power, primarily governed by inlet pressure and mass flow rate rather than the thermal input alone.

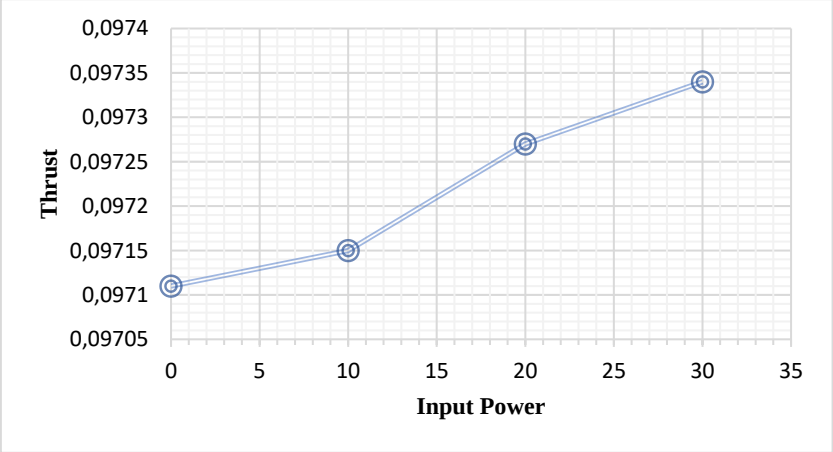


Figure 7. Input Power vs Thrust

In conclusion, while increased input power significantly improves the specific impulse and hence the propulsion system's efficiency, it has a minimal impact on thrust. These insights underline the importance of optimal power management, where power input should be carefully balanced to maximize efficiency gains without unnecessary resource consumption, particularly in small satellite propulsion applications where power availability is critically limited.

Thanks and Information Note

Special thanks to Sivas University of Science and Technology for their continued support and valuable contributions to our scientific research.

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IMPACT OF ZrO_2 AND Ni ADDITIVES ON THE PROPERTIES OF Al_2O_3-BASED CERAMICS IN THE TERAHERTZ BAND

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ABSTRACT

The Terahertz (THz) frequency range becomes increasingly important for next-generation systems. Thus, the selection and properties of materials in this frequency band are crucial for improving system efficiency. In this regard, ceramics have recently gained significant attention for THz applications, due to their unique properties. In this context, we investigate the dielectric properties of zirconium oxide (ZrO_2) and nickel (Ni)-added aluminium oxide (Al_2O_3)-based ceramics in the THz range. The fabricated ceramics are characterized using THz time-domain spectroscopy (THz-TDS), a powerful analytical technique that employs THz radiation. We analyse the impact of ZrO_2 and ZrO_2+Ni additives on the dielectric properties of Al_2O_3-based ceramics. Key parameters examined include refractive index, permittivity, absorption coefficient, and loss tangent. Our findings reveal that Al_2O_3-based ceramics with ZrO_2 + Ni additives exhibit a higher dielectric constant and refractive index than the pure Al_2O_3 and ceramics containing only ZrO_2 additives. Furthermore, these ceramics' loss tangent is lower than those with only ZrO_2 additives. However, the combination of ZrO_2 and Ni additives increases the permittivity of Al_2O_3-based ceramics. These results facilitate the selection of suitable composites and enhance the dielectric properties of Al_2O_3-based ceramics, paving the way for high-performance THz applications, especially for next-generation 6G communication systems.

Keywords: Terahertz, Aluminium Oxide-based Ceramics, Zirconium Oxide, Nickel, Dielectric Properties.

Introduction

Terahertz radiation is the frequency range between infrared and microwave in the electromagnetic spectrum, ranging from 0.1 to 10 THz (Hakobyan et al., 2022). Recent advances in photonics and microelectronics have led to significant progress in THz functional devices (Purlu et al., 2025). THz photonics has attracted a lot of attention, especially for its low scattering, high spectral bandwidth, low photon energy, and free space propagation (Hakobyan et al., 2022). The applications of terahertz technologies include radar, high-speed wireless communications, non-destructive testing, spectroscopy, materials characterization, and space technologies (Calvo-de la Rosa et al., 2020; Pałka et al., 2023; Purlu et al., 2025). The dielectric ceramics with high permittivity and low losses are promising materials for the THz frequency band (Hakobyan et al., 2022).

Advanced ceramics are a class of engineered materials that are ideal for demanding technological applications because of their unique mechanical, thermal, and chemical stability. Ceramics are materials characterized by excellent wear resistance, high hardness, corrosion resistance, and high melting points, making them suitable for a wide range of applications from engineering to medicine (Ayode Otitoju et al., 2020). The dielectric properties of ceramic materials in the terahertz (THz) frequency range make them attractive for high-frequency device applications. The characteristic properties of Al_2O_3 ceramics in the THz frequency band, such as low dielectric constant and low dielectric loss factor, make it a potential candidate material for various dielectric-based technological applications such as dielectric resonator structures, integrated circuit applications, and interconnection antenna systems (Hakobyan et al., 2022; Purlu et al., 2025).

The microstructural properties of ceramic materials, such as grain size, composition, and porosity, directly affect their dielectric properties. The performance of the material in the THz range can also be improved by modifying these properties (Cao et al., 2023). MacDougall et al. investigated the optical properties in the terahertz frequency range of monoclinic zirconia samples with different powder sizes (MacDougall et al., 2024). Purlu et al. examined the effect of samarium oxide and zirconia addition to Al_2O_3 ceramics on the microstructure and dielectric properties in the THz frequency range. As a result of the study, it was observed that the dielectric constant and refractive index of the samples containing ZrO2, Sm_2O_3, and ZrO_2-Sm_2O_3 additives improved according to pure Al_2O_3 (Purlu et al., 2025). At the same time, the THz frequency can be used to detect the internal structural defects of ceramic samples in a non-destructive method. This enables it to play an important role in the quality control and characterization of ceramic components. Hokabyan et al. performed terahertz characterization of pure Al_2O_3 and Al_2O_3-ZrO_2 ceramics produced with different powder sizes and porosity ratios. The porosity ratios of the samples were determined by a THz time-domain spectroscopy (THz-TDS) system. In addition, a relationship between porosity ratio, grain size, and dielectric properties was attempted to be determined (Hakobyan et al., 2022). Palka et al. visualized the defects in the internal structure of hexagonal Al_2O_3 ballistic test samples by a THz-TDS method (Pałka et al., 2024).

In the present study, the densification, microstructure, and dielectric properties (refractive index, permittivity, absorption coefficient, and loss tangent) of the Al_2O_3-based ZrO_2 and ZrO_2-Ni additives were investigated in the terahertz range. The Ni-added samples were produced via the heterogeneous precipitation method. The fabricated ceramics are analyzed using THz time-domain spectroscopy (THz-TDS), an advanced analytical method that utilizes THz radiation.

Materials and Methods

The raw materials used in this work were α-Al_2O_3 powder (Alfa Aesar, 99.5% purity, 0.25–0.45 μm), ZrO_2 powder (3 mol% Y_2O_3 stabilized, Inframat Advanced Materials, <0.5μm), nickel nitrate hexahydrate ($Ni(NO_3)_2 \cdot 6H_2O$, 98% purity, Alfa Aesar), ammonium bicarbonate (NH_4HCO_3, precipitant, Sigma Aldrich, 99% purity), polyacrylic acid (dispersant, MSE Tech Co. Ltd, Turkey), polypropylene carbonate (PPC, binder, QPAC 40, Empower Materials, USA).

The Al_2O_3 ceramics were added with ZrO_2 and Ni at 5 vol.% and 1 vol.%, respectively. The heterogeneous precipitation technique was utilised to produce nano-Ni particles on the Al_2O_3 ceramic. The heterogeneous precipitation method is an effective technique used to obtain nano-sized metal particles with homogeneous distribution in the ceramic matrix (Yıldız et al., 2021).

Initially, the solution of $Ni(NO_3)_2$-$6H_2O$ in distilled water was prepared in the required quantities to obtain a 1 vol.% Ni content in the Al_2O_3-ZrO_2-Ni composite. Subsequently, this solution was ball milled with Al_2O_3 powder, ZrO_2 powder, and polyacrylic acid as a dispersant. Meanwhile, an aqueous solution of precipitant NH_4HCO_3 was prepared and added dropwise to the milled mixture under vigorous stirring. Through this process, the Al_2O_3 and ZrO_2 powder mixture was coated with the amorphous $NiCO_3 \cdot 2Ni(OH)_2 \cdot 2H_2O$ phase formed as a result of the reaction. The precipitant added mixture was dried and then crushed in an agate mortar. The prepared powder mixture was calcined at 500°C in a pressureless air environment for 2 hours, and nano nickel oxide (NiO) was obtained in the form of particles from the amorphous phase $NiCO_3.2Ni(OH)_2.2H_2O$. The calcined powder was subjected to heat treatment at 700°C in a 10% H_2 + 90% Ar atmosphere for 4 hours, and the reduction of nickel oxide to Ni metal was ensured. As a result of this process, Al_2O_3-ZrO_2-Ni composite powder was obtained. The composite powder was mixed with the binder solution (PPC + acetone) and dried. The dried powder was crushed and sieved via a 90 μm sieve. The granulated powders were first pressed in a uniaxial press (under 40 MPa pressure), followed by a cold isostatic press (under 200 MPa pressure). The sintering process was carried out at 1550°C under a 10% H_2+90% Ar atmosphere for 2 hours. Sintering was carried out step by step to remove PPC from the structure. In Figure 1, the production process of the Ni-containing samples is illustrated schematically.

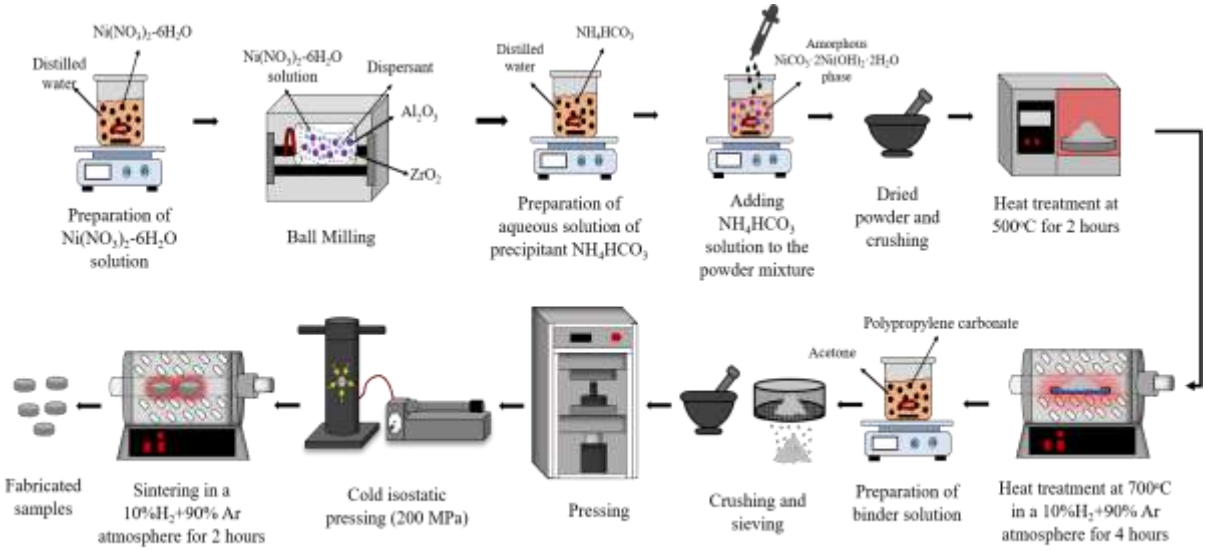


Figure 1. Fabrication process of nickel-containing samples

In the fabrication of the non-Ni ceramics, the required amount of ceramic powders was ball milled in distilled water with polyacrylic acid and dried. Then the powder was crushed in an agate mortar, and the dispersant was removed from the samples by heat treatment at 500°C (2 hours in air). The prepared binder solution was added to the powder, and the acetone in the mixture was evaporated, and the powder was dried. The pressing and sintering stages were performed under the same conditions as the nickel-containing samples. Finally, the samples were sanded with a lapping machine and polished with a 1 μm diamond solution.

The Archimedes method was used to analyse the densification of the produced samples. The samples were analysed by scanning electron microscopy (SEM) for grain size, grain morphology, and distribution of additive phases investigations. The crystalline phases and structures of the compositions were analysed by the X-ray diffraction (XRD) method. The dielectric properties (refractive index, permittivity, absorption coefficient, and loss tangent) of the samples in the terahertz band were characterised by THz time-domain spectroscopy (THz-TDS). Terahertz characterisations were performed in the frequency range 0.3-1.5 THz.

Findings and Discussion

Table 1 shows the relative density results of the produced samples. It is seen that the sintering of pure Al_2O_3 is positively affected, and its densification increases with the addition of additives. Especially, with the addition of 5vol.% ZrO_2, the density value has reached 98.5%. In the case of Al_2O_3-ZrO_2-Ni composites, although the density is also increased compared to pure Al_2O_3, the densification is lower compared to the composition containing only ZrO_2. This phenomenon can be attributed to the low wettability of alumina and zirconia by liquid nickel (118° for ZrO_2, 128° for Al_2O_3). Low wettability leads to weakening of the interface, and the densification is negatively affected (Yıldız & Tür, 2019).

Table 1. Relative density values of the fabricated samples

Composition	Relative Density (%)
Pure Al_2O_3	95.7
Al_2O_3-ZrO_2	98.5
Al_2O_3-ZrO_2-Ni	97.7

The XRD graphs of the sintered samples are given in Figure 2. In the graph, the symbols "♦" and "♦" indicate the peaks of Ni and ZrO_2, respectively. When the peaks were analyzed, the presence of Al_2O_3 and tetragonal ZrO_2 peaks were determined in the composites. Moreover, Ni peaks are clearly visible in the Ni-containing composition. Also, the formation of undesirable secondary phases (monoclinic zirconia and nickel aluminate spinel ($NiAl_2O_4$)) was not observed in XRD analysis.

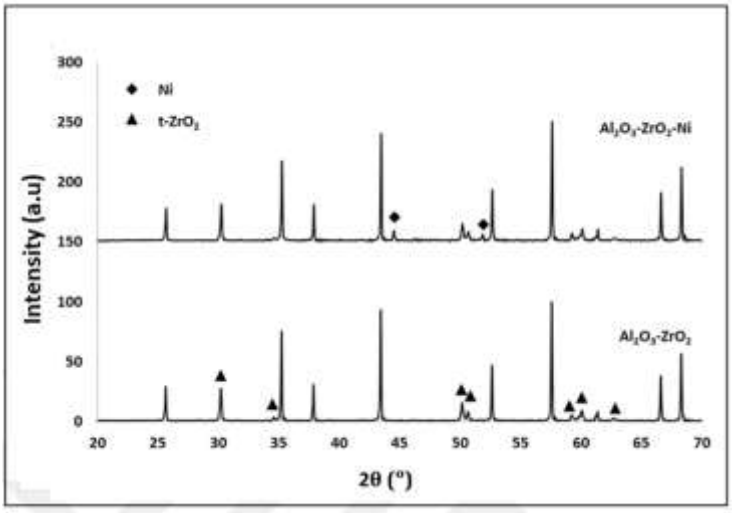


Figure 2. XRD graphs of sintered samples

The SEM images of the Al_2O_3-based samples produced are presented in Figure 3. The gray regions in the images are Al_2O_3, and the white regions are ZrO_2 and Ni. The SEM images reveal that the additives are distributed almost homogeneously in the microstructure. It is also observed that ZrO_2 and Ni particles are mostly located at grain boundaries and triple junctions. This prevented excessive grain growth due to the high temperature during sintering.

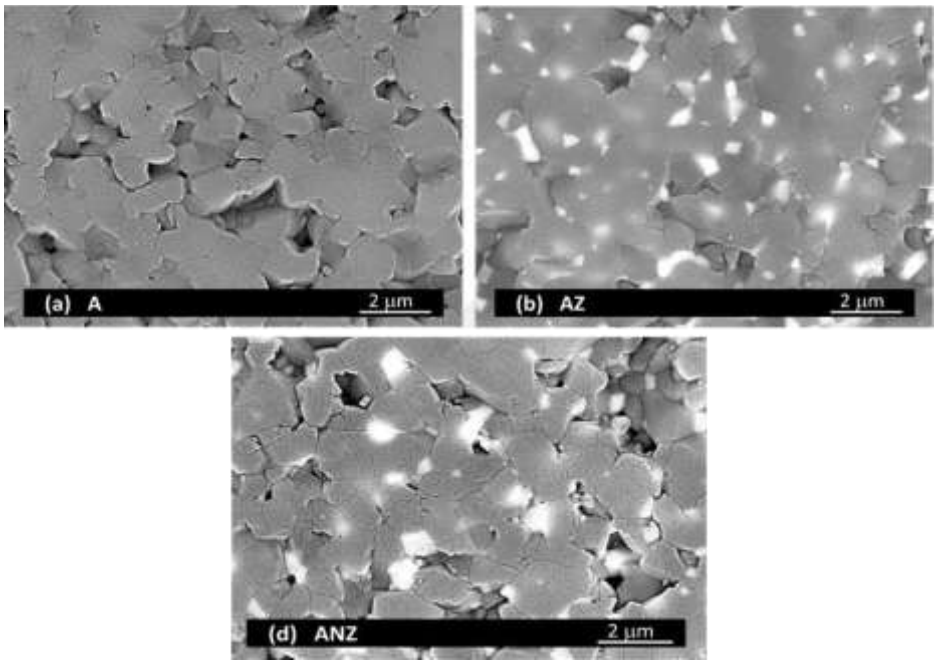


Figure 3. The SEM images of the (a) Pure Al_2O_3, (b) Al_2O_3-ZrO_2 and (c) Al_2O_3-ZrO_2-Ni

Figure 4 shows the variation of refractive index with frequency. The refractive index curves for all three ceramic compositions remain essentially flat across the 0.3–1.5 THz band, indicating minimal dispersion in this frequency range. The addition of ZrO_2 to Al_2O_3 shifts the refractive index upward relative to pure Al_2O_3, while the further inclusion of Ni produces the highest

refractive index, reflecting an increased dielectric constant. This combination of elevated, frequency-stable refractive index in the Al_2O_3+ZrO_2+Ni sample makes it particularly attractive for THz applications that demand high permittivity without added dispersion.

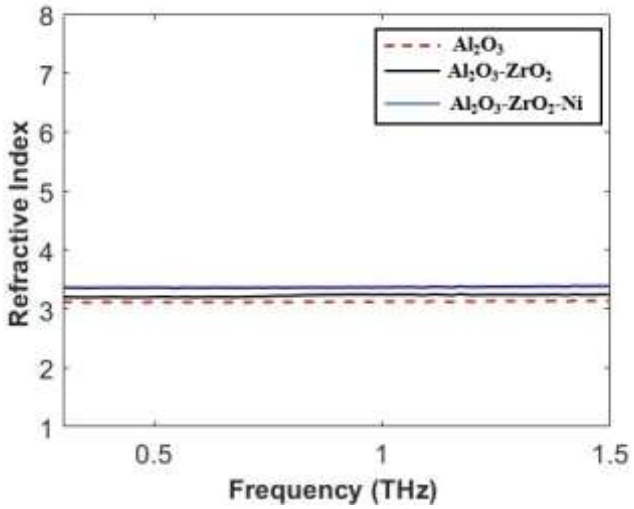


Figure 4. The variation of refractive index with frequency in the produced ceramics

The variation of the absorption coefficient in the terahertz frequency range is given in Figure 5. The absorption coefficient for all three compositions exhibits a slight upward trend across the measured 0.3–1.5 THz range, reflecting frequency-dependent absorption behavior. The Al_2O_3+ZrO_2 sample shows the highest absorption values, likely due to increased scattering and defect states introduced by the ZrO_2 additive. Incorporation of Ni into the Al_2O_3+ZrO_2 matrix reduces the absorption compared to the ZrO_2-only sample, balancing absorption losses with the observed permittivity enhancement.

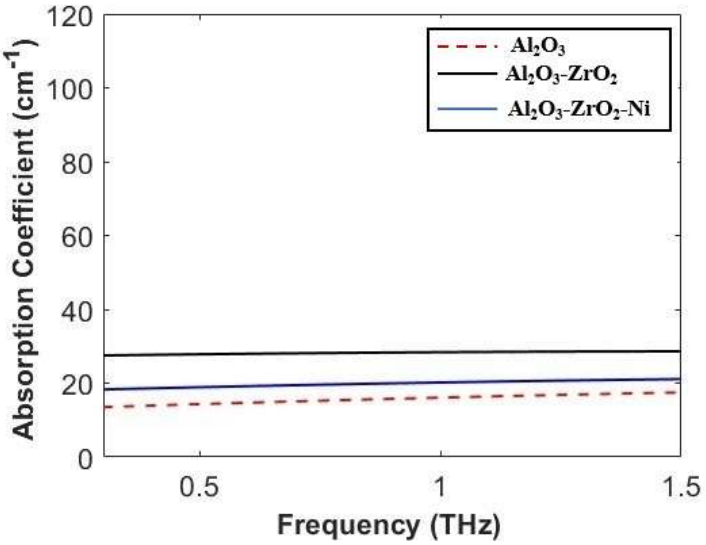


Figure 5. The variation of the absorption coefficient in the terahertz frequency range

The trend of the loss tangent with frequency is presented in Figure 6. The loss tangent for all samples decreases markedly with increasing frequency, indicating reduced dielectric losses at higher THz frequencies. The Al_2O_3+ZrO_2 composition exhibits the highest loss tangent across the band, while the addition of Ni to the ZrO_2-doped matrix lowers the loss tangent closer to that of pure Al_2O_3. This frequency-dependent loss reduction in the Al_2O_3+ZrO_2+Ni sample underscores its potential for low-loss THz applications, especially above 1 THz.

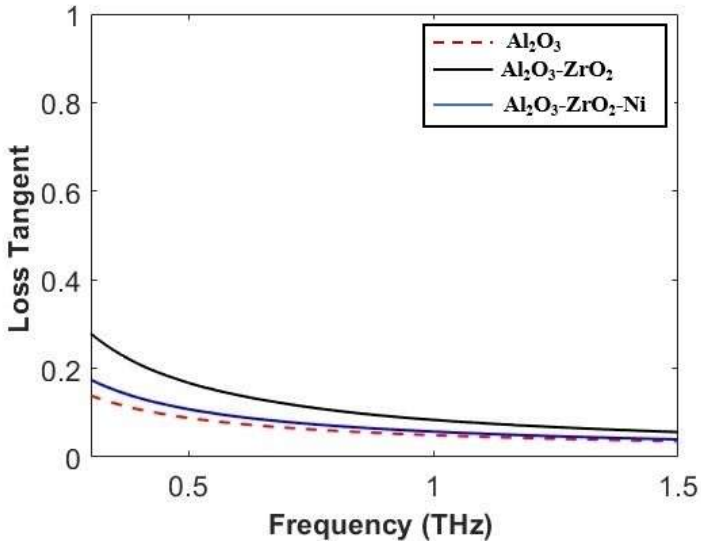


Figure 6. The variation of the loss tangent with the frequency

The graph in Figure 7 presents the variation of the permittivity depending on the frequency. The permittivity of all three ceramic compositions exhibits a slight upward trend over the 0.3–1.5 THz range, reflecting increased polarization at higher frequencies. The Al_2O_3+ZrO_2 sample shows higher permittivity than pure Al_2O_3, while the Al_2O_3+ZrO_2+Ni composition achieves the highest values, confirming the synergistic effect of both additives on dielectric polarization. This combination of elevated and frequency-stable permittivity underscores its suitability for THz devices requiring enhanced dielectric response without significant dispersion.

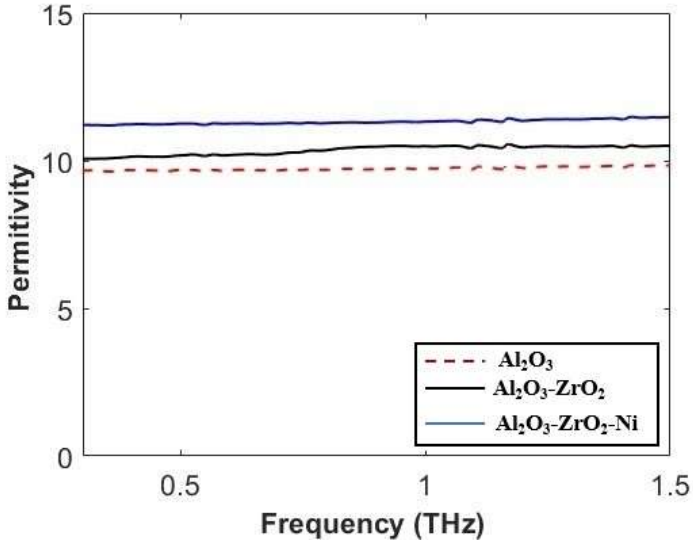


Figure 7. The variation of the permittivity depending on the frequency.

Conclusion and Recommendations

In this paper, the Al_2O_3-based ceramics containing 5vol.%ZrO_2 and 1vol.%Ni were produced by the heterogeneous precipitation method. The densification behaviour, microstructure, and dielectric properties in the range of 0.3-1.5 THz were investigated. The THz band properties of the samples were characterized by a THz time-domain spectroscopy (THz-TDS) system.

- In the study, the Ni precipitation process was successfully carried out, and it was observed that ZrO_2 and nano-sized Ni particles were homogeneously dispersed in the Al_2O_3 matrix. Besides, the ZrO_2 and Ni particles are located at the grain boundaries and triple junctions in the microstructure, so there is no excessive grain growth. At the same time, it was observed that the densification increased with ZrO_2 and Ni additives in the sintered samples.
- When the dielectric properties of the samples in the terahertz band were examined, it was observed that the refractive index and permittivity were stable in the range of 0.3-1.5 THz in all compositions. It is seen that the loss tangent exhibits a marked decrease in this range. It was observed that the Al_2O_3-ZrO_2-Ni composites have higher dielectric constant and refractive index compared to the pure Al_2O_3 and the Al_2O_3-ZrO_2 composites. Consequently, it was determined that the additives improved the dielectric properties of Al_2O_3-based ceramics. It is inferred that these compositions have potential in THz applications.

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SIGNAL TO NOISE RATIO ANALYSIS OF HERMITE COSINE-HYPERBOLIC VORTEX GAUSSIAN BEAM IN TURBULENT FREE-SPACE OPTICAL COMMUNICATION LINKS

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ABSTRACT

One of the critical parameters of Free-Space Optical (FSO) communication links is the Signal to Noise Ratio (SNR). Higher SNR means the signal power is much stronger than the noise power, this makes the system more resilient to turbulence-induced distortions and insures more reliable propagation of the laser beams. In this regard, the SNR of Hermite Cosine-hyperbolic Gaussian vortex beams (HChvGB) in turbulent FSO communication links is examined. HChvGB have been recently introduced and known for their unique properties. Thus, in this study, the topological charge, beam order and decentred parameter impact on the SNR behavior of HChvGB is analyzed. For beams with lower decentred parameter, as the beam order increases the SNR increases then at the order of 4 SNR starts to decrease. Besides that, for links longer that 2 km, beams with lower decentred parameter and having a topological charge of 2 have the advantage of increasing the SNR level. As a result, the provided results will play a significant role in the design and performance improvement of the FSO communication links, laser detection and ranging (LIDAR) systems and directed infrared counter measure systems (DICM).

Keywords: Hermite Cosine-hyperbolic Vortex Gaussian beams, Free-space optical communication links, turbulent atmosphere, SNR

Introduction

In recent years, requirement for the high date rates, high-level security, ultra-low latency, and low power consumption pave the way for development of FSO communication systems(Al-Gailani et al., 2021). However, atmospheric turbulence poses challenge for FSO systems, which generate refractive index fluctuations in the propagation path. These fluctuations lead to beam wander, scintillation, phase front distortion, and overall signal degradation, which is adversely affecting the system's SNR(Wang et al., 2021). To address these issues, various optical beams, such as Hermite-Gaussian (HG), Laguerre-Gaussian (LG), Bessel Gaussian and Airy Gaussian have explored by the researchers and their propagation characteristics under the atmospheric turbulence are studied (Du et al., 2023; Jin et al., 2021; Wuming et al., 2021; Zhang et al., 2022). Among these, HChvGB have emerged as a promising candidate due to their unique combination of spatial symmetry, phase singularities, and the ability to customize beam structure through tunable parameters such as topological charge, beam order, and decentred parameters. In a literature survey, the propagation properties of HChvGB in atmospheric turbulence are investigated based on the extended Huygens–Fresnel diffraction integral. The influence of the turbulence strength on the intensity distribution under the change of beam parameters conditions is illustrated (Hricha et al., 2021). Besides that, influence of the beam parameters on the beam propagation factor (M^2-factor) of the HChvGB is investigated by using the second-order intensity moments (Ahlane et al., 2024). Despite the given studies, to the best of our knowledge, comprehensive studies evaluating their SNR performance under turbulent atmospheric conditions has never studied before. Therefore, this study aims to analyze the influence of key beam parameters namely topological charge (m), Hermite polynomial order (p, q), and decentred parameter (b) on the SNR behavior of HChvGB in FSO communication links using a random phase screen turbulence model.

Materials and Methods

The HChvGB in the rectangular coordinate system and z axis refers to propagation plane, electric field intensity of beam in the source plane (z = 0) can be expressed by equation (1) (Hricha et al., 2021);

$$(x_0, y_0, z = 0) = H_p\left(\sqrt{2}\frac{x_0}{w_0}\right) H_q\left(\sqrt{2}\frac{y_0}{w_0}\right) \cosh\left(b\frac{y_0}{w_0}\right) e^{-\left(\frac{{x_0}^2+{y_0}^2}{{w_0}^2}\right)} \left({x_0}^2 + i{y_0}^2\right)^m \quad (1)$$

where (x_0, y_0) are the transverse Cartesian coordinates at initial plane, w_0 is the waist radius of gaussian part, p, q are the Hermite polynomial orders, cosh denotes the hyperbolic-cosine function, b is decentred parameter related to the cosh part, m is topological charge.

Random phase screen model was used to investigate SNR for different parameters of the HChvGB beam propagating in the atmospheric turbulence conditions. This model requires dividing the propagation distance (L) into N_s intervals $\Delta L = \frac{L}{N_s}$ separated by thin phase screen planes. Accordingly, the received electric field intensity after free space propagation can be computed using (2)(Bayraktar et al., 2024);

$$u_r(r, mL) = F^{-1}\left[F\left[u_s(r, (m-1)\Delta L) exp\left(j\phi(r)\right)\right] H(f)\right] \quad (2)$$

Here F, F^{-1}, correspond to Fourier transform and its inverse, $H(f)$ Fourier transform of transfer function, $r = (r_x, r_y)$receiver plane coordinates, $f = (f_x, f_y)$ are spatial frequencies, ΔL equal to partial propagation distance, $\phi(r)$ denotes the phase power spectral density for each individual in the random phase screen model. In this study the Von-Karman power spectral

density is used to generate random phase screen model which is shown in (3)(Akcan et al., 2024);

$$\phi_{\emptyset}(f) = \frac{0.0036LC_n^2k^2L_0^{11/3}}{(L_0^2|f|^2+1)^{11/6}} exp[-1.1265I_0^2|f|^2] \quad (3)$$

Here, C_n^2 is the refractive index structure constant, l_0, L_0 are the inner and outer scale of turbulence. The aperture averaged scintillation is calculated using the received field as given (4)(Dalgac et al., 2025);

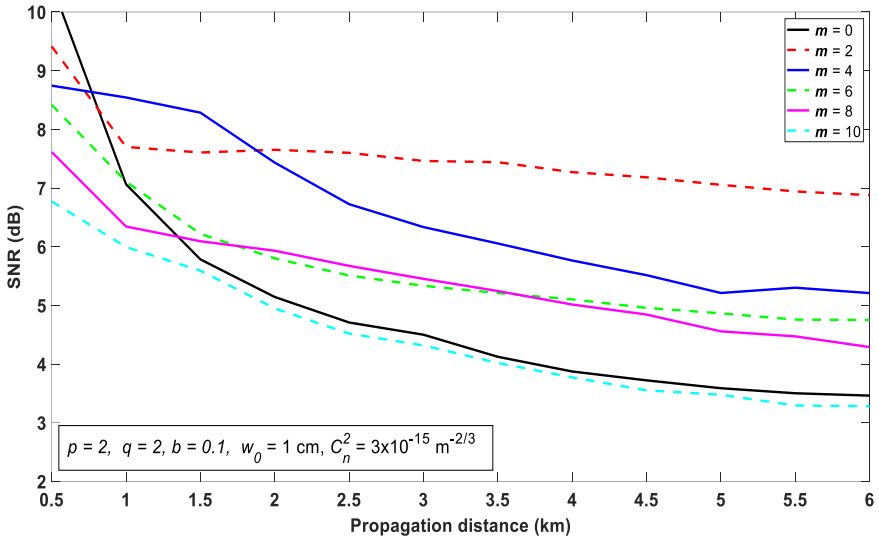
$$m_A{}^2 = \frac{\frac{1}{N}\left[\int_0^{r_x}\int_0^{r_y}\sum_{i=1}^{N} u_r(r,L)u_r{}^*(r,L)dr_x dr_y\right]^2 - \left[\frac{1}{N}\int_0^{r_x}\int_0^{r_y}\sum_{i=1}^{N} u_r(r,L)u_r{}^*(r,L)dr_x dr_y\right]^2}{\left[\frac{1}{N}\int_0^{r_x}\int_0^{r_y}\sum_{i=1}^{N} u_r(r,L)u_r{}^*(r,L)dr_x dr_y\right]^2} \quad (4)$$

where N indicates the number of realizations taken as 500 in the simulations. After obtaining the aperture averaged scintillation index, due to the dominancy of scintillation index against other noise types, SNR is calculated as it is defined in (5) (Eyyuboğlu & and Bayraktar, 2015);

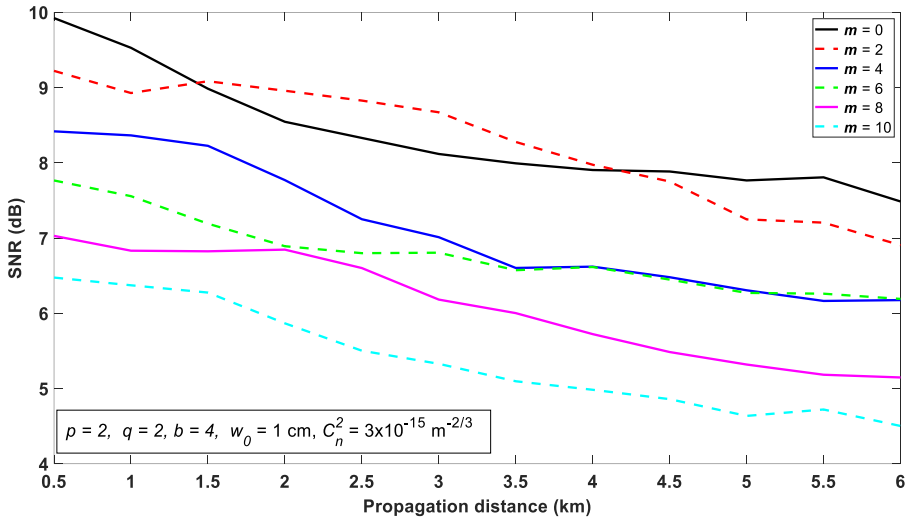
$$\text{SNR} \sim \frac{1}{m_A^2} \quad (5)$$

Findings and Discussion

In this study, the SNR of HChvGB in turbulent FSO communication links is examined. The communication link operates at 1550 nm and communicates through a 6 km atmospheric channel with a refractive index structure constant of $C_n^2 = 3 * 10^{-15}\text{m}^{-2/3}$. The number of screens inserted between source and receiver plane is 50 and their grid size is 256*256. The topological charge effect on the SNR of HChvGB when *b=0.1* and *b=4* were investigated and obtained results were illustrated as given Figure 1(a) and Figure 1(b), respectively. It can be said that, as the topological charge increases, SNR tend to decreases for shorter communication links up to 1-2 km regardless of the decentred parameter. Also, increasing of decentred parameter leads to decrease of SNR. For links longer than 2 km, beams with lower decentred parameter and having a topological charge of 2 have the advantage of increasing the SNR level.



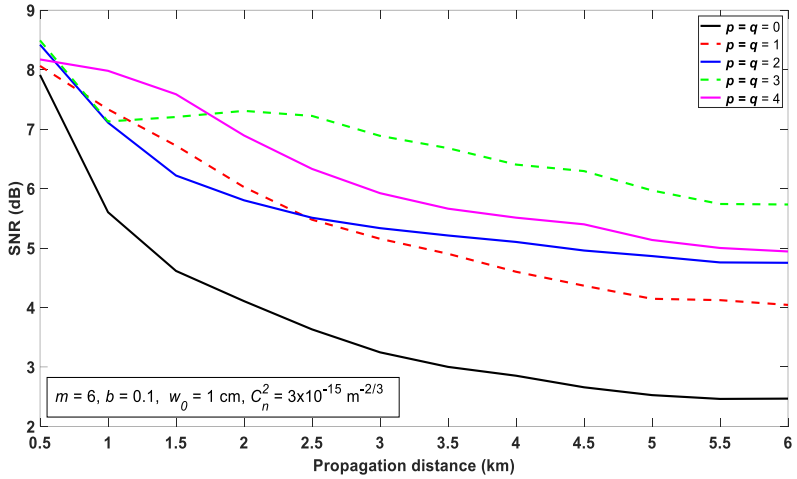
(a)



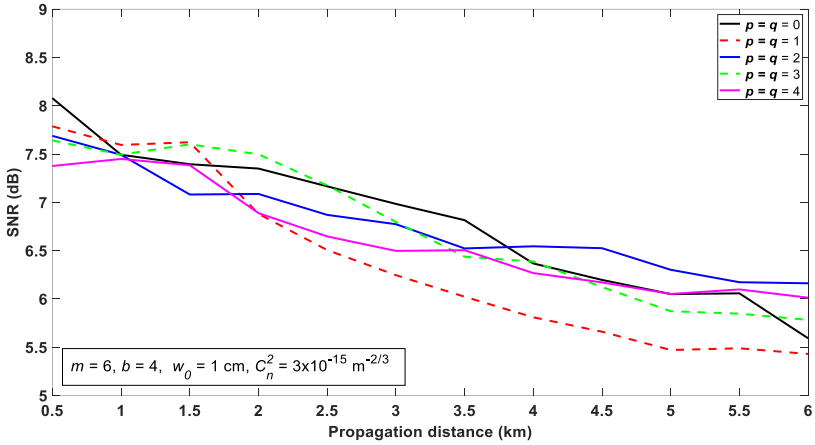
(b)

Figure 1. The effect of the topological charge on the SNR of the HChvGB. (a) $b = 0.1$, (b) $b = 4$.

In addition to topological charge, the impact of Hermite polynomials order on the SNR of HChvGB was also analyzed in Figure 2. As given Figure 2 (a) and Figure 2(b), Hermite polynomial order vary from 0 to 4 in the case of *b=0.1 and b=4*, respectively. Figure 2 (a) demonstrate that, for beams with lower decentred parameter, as the beam order increases the SNR increases then at the order of 4 SNR starts to decrease. In contrast, Figure 2 (b) represent that for higher decentred parameter, SNR generally lower and exhibits a flatter profile across the beam orders.



(a)



(b)

Figure 2. The effect of the Hermite polynomials orders on the SNR of the HChvGB. (a) $b = 0.1$, (b) $b = 4$.

Conclusion and Recommendations

In this study, the behavior of the SNR for HChvGB propagating through FSO communication links was investigated by the help of random phase screen model. The effects of topological charge, Hermite polynomial order, and decentred parameter on SNR performance were systematically analyzed. The results reveal that increasing the topological charge generally reduces the SNR, especially for shorter propagation distances. However, for longer distances, beams with a low decentred parameter and a topological charge of 2 demonstrate superior SNR performance. Additionally, the influence of Hermite beam order is non-monotonic: as the order increases, SNR initially rises, reaches a peak at order 4, and then declines. A higher decentred parameter consistently leads to reduced SNR. The results provide guidance for designing robust FSO systems, as well as other optical platforms such as LIDAR and DIRCM, where controlling beam shape and vortex structure is critical.

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DESIGN AND PRODUCTION OF A REUSABLE ERGONOMIC VIDEO LARYNGOSCOP

YENİDEN KULLANILABİLİR ERGONOMİK VİDEO KAMERALI LARİNGOSKOP TASARIM VE ÜRETİMİ

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ABSTRACT

Laryngoscope is a medical device used by healthcare professionals to examine a patient's larynx. The tongue and epiglottis are lifted using the extension of the laryngoscope and are used in emergency rooms or ambulances to help open the airways of patients. Traditional laryngoscopes require healthcare professionals to adjust the patient's neck, lift the tongue with the laryngoscope, and bend the practitioner to view the level of the mouth. This procedure is challenging and requires experience. If the laryngoscope is applied incorrectly, irritation and complications may occur in the applied area and may also adversely affect the interventions made on the patient's respiratory tract. For this reason, within the scope of this working, a laryngoscope with a camera was developed in order to prevent such negativities and facilitate laryngoscope application. Mechanical parts were designed using computer-aided drawing programs, paying attention to ergonomics and usage in laryngoscope applications. In order to prototype and check the suitability of the designs, their production was carried out using jointed manufacturing methods. Then, the mechanical parts of the final product were produced using DLP printers. In the video laryngoscope device, electronic systems and software of our design were used. The laryngoscope device produced with the designed electronic systems can perform imaging and wireless image transfer simultaneously. In addition, the device can be used for several hours without any cable requirement with its battery. As a result of the studies, the design and production of a laryngoscope with an ergonomic grip, which can be used remotely, and which can be viewed from a distance, has been designed and produced. With this design, an important step has been taken in increasing the ease of use of the laryngoscope, reducing the need for experience, and preventing complications that may occur in patients.

Keywords: Laryngoscope, Biomedical Engineering, Respiratory Systems,

Introduction

With the advancement of technology, the use of imaging devices in the field of medicine has become increasingly widespread. Especially in medical devices such as surgical instruments and endoscopy systems, imaging technologies play a crucial role in medical diagnosis and surgical procedures. Another imaging device used in the medical field is the video laryngoscope. Since its invention, the laryngoscope has played an important role in the diagnosis of throat diseases, surgeries, and medical education. While traditional laryngoscopes do not contain any electronic components, video laryngoscopes enable real-time visualization of the procedure through the use of a camera and display, allowing the process to be completed more quickly.

Today, the laryngoscope is a medical device frequently needed, particularly in intubation procedures. However, when performed by inexperienced medical personnel, intubation can present significant challenges and may lead to undesirable outcomes. The use of a video laryngoscope can facilitate the intubation process and help minimize the likelihood of potential complications. Figure 1 shows different types of laryngoscope devices. Video laryngoscopes with various designs are available from different manufacturers. These designs have their own advantages and disadvantages relative to one another.



Figure 1. Different Laryngoscope devices

Today, medical devices incorporating imaging technologies are widely used in surgical instruments and endoscopic systems (Matek, Kolek, Klementova, Michalek, & Vymazal, 2021). The integration of imaging technologies in medical devices allows for faster and more accurate diagnosis and treatment. One such device that utilizes imaging technology is the laryngoscope used in intubation procedures. Currently, models of laryngoscopes with integrated imaging capabilities are available. These advanced models enable intubation procedures to be performed more quickly and accurately (Tabari, Soltani, Zirak, Alipour, & Khazaeni, 2013; Liu et al., 2019). Studies have shown that the success rate of intubation using a video laryngoscope exceeds 95%, whereas with traditional laryngoscopes, the success rate may fall below 50% depending on the conditions (Özkan, 2011).

In addition to patient interventions, video laryngoscope devices can also be utilized in the training of medical personnel. A study examining the impact of video laryngoscopes in training demonstrated that training with such devices improved success rates and reduced intubation

times (Malito, Mathias, Junior, Correa, & RamalhoBardauil, 2021). The use of imaging in the laryngoscopy method is highly important for ensuring the success of intubation procedures.

Numerous studies on video laryngoscopes exist in the literature. Some of these studies proposed cost-effective and rapid solutions by using micro-cameras connected to tablets or smartphones via USB cables (Kim et al., 2020; MD, MD, & MD, 2018). However, these devices are not suitable for medical applications due to issues such as lack of product certification, sterilization difficulties, and concerns regarding patient data privacy. Other studies have proposed fully developed video laryngoscope devices. For instance, in 2009, the company CMAC designed a video laryngoscope consisting of a camera and an external monitor mounted on a stand, allowing for visual support during intubation (Cavus et al., 2009). The study reporting the initial use of this device highlighted that even in cases where intubation was extremely challenging with a traditional laryngoscope, video laryngoscopy enabled successful intubation on the first attempt.

The laryngoscope models developed by King Vision feature a built-in screen located on the handle, directly connected to the laryngoscope (Murphy et al., 2014). Powered by an internal battery, this device is compact and cable-free, making it more portable. A study on this model reported that intubation was successfully performed in patients who posed difficulties for traditional laryngoscopy and that the duration of the procedure was reduced. In addition to video laryngoscopes, wireless laryngoscopes capable of transmitting images without cables are also found in the literature (Huang, Yang, & Feng, 2017; Lai & Wu, 2019; Guerra-Hernández, Vidaña-Martínez, & Camacho-Juárez, 2020). These devices are particularly helpful when intubation is performed by less experienced personnel or during training sessions. Some wireless laryngoscopes include built-in screens, while others are designed to transmit images to external devices such as smartphones or tablets.

A video laryngoscope model developed and manufactured in Turkey also exists. The device, named Scoper, was developed by Gazi University and features a micro-USB camera connected to a tablet display. However, due to its cabled and stand-mounted structure, it is not suitable for use in every environment. Additionally, it lacks wireless capability and can only display images on the tablet screen.

In this study, a laryngoscope prototype is aimed to be developed, which will include an integrated camera and display, making it portable and suitable for use in any setting. With the inclusion of wireless image transmission, it is intended to reduce the duration required for training and the intubation procedure itself. This study is expected to contribute to the literature in terms of local innovation by proposing a wireless and modular video laryngoscope, while also aiming to provide economic benefits through a cost-effective design.

Materials and Methods

This section outlines the design and implementation of the video laryngoscope system. The first subsection details the imaging system, the second addresses the wireless transmission mechanism, and the final subsection presents power consumption calculations and battery specifications.

Imaging System

The imaging system includes a digital camera (OV2640), a microcontroller (ESP32-S3), and a 320×240 resolution TFT screen. To ensure usability and smooth display, the selected components target a frame rate (FPS) of at least 15. The OV2640 camera, with a parallel

interface and support for 20 MHz clock speed, enables high FPS rates and transmits both compressed (JPEG) and uncompressed data efficiently.

The image captured by the camera is transferred to the ESP32-S3, where it is decompressed before being displayed on the screen. Preliminary tests indicate that decoding a 320×240 JPEG image takes approximately 20 ms, while screen transfer over SPI takes about 30 ms, totaling 50 ms per frame—sufficient for the 15 FPS target.

A GUI is implemented using the open-source LVGL graphics library, chosen for its modern interface support and compatibility with resource-constrained microcontrollers. Menu designs are rendered in English due to font limitations.

To improve image quality when needed, an IPS panel TFT may replace the initial display, offering better color accuracy during intubation procedures.

Wireless Transmission

In addition to local display, the device wirelessly transmits captured images to a remote server using Wi-Fi and the User Datagram Protocol (UDP). UDP's low-latency, lightweight structure makes it well-suited for this real-time application.

The ESP32-S3 establishes a connection to a fixed-IP server and continuously streams 320×240 JPEG images, typically sized between 4–5 kB. A web service on the server handles multiple client connections (via web, desktop, or mobile apps) and authorizes them using HTTP-based authentication.

Battery and Charging System

The device is powered by an integrated lithium-ion battery (2S configuration, 1200 mAh). In contrast to removable batteries, this setup allows the device to operate while charging. The target operational duration is at least 2 hours.

Assuming an average power draw of 500 mA at 5 V, the estimated power consumption is 2.5 Wh. Accounting for battery health (80% usable capacity), the system is expected to run for over 3 hours. AA-sized 14500 Li-ion batteries are selected to minimize space usage within the device.

Mechanical Structure

Mechanical housing was designed and produced to support and protect the electronic components of the video laryngoscope. This section summarizes the design, validation, and prototyping process.

Mechanical Design

Following the development of electronics, a protective and ergonomic mechanical enclosure was created using SolidWorks. The housing serves both to shield internal components from moisture and to enable comfortable handling. Special attention was paid to ergonomics, designing the grip to fit the human hand with contours and, if necessary, texture surfaces for secure handling.

Given that the laryngoscope is inserted through the mouth into delicate tissue areas, design accuracy is critical. Any design flaw could cause patient discomfort or harm. The electronics were positioned to remain in the grip section, simplifying disinfection and minimizing exposure to contaminants. The overall geometry was optimized to remain lightweight and compact for ease of use and storage.

To accommodate different patient sizes and age groups, the blade portion (the insertable tip) was designed to be detachable and replaceable, while the grip and electronics remain consistent across use cases. The connection mechanism was designed to be simple and secure.

Since considerable force may be required during intubation, the mechanical structure was engineered to withstand stress without fracture. Wall thickness and geometry were carefully calculated to prevent stress concentrations and ensure structural integrity.

Design Validation

Finite Element Analysis (FEA) was conducted to validate the mechanical design. The 3D model was meshed using Hypermesh and analyzed in ANSYS under static load conditions. The grip section was fixed, and a maximum expected force was applied to the blade end. Results from the analysis guided design refinements to improve durability and ergonomic performance without the need for repeated physical prototyping.

Prototyping and Fabrication

After validation, a prototype was fabricated using additive manufacturing for rapid prototyping. The design was exported as an STL file and prepared for printing in Halot Box software. Printing was performed using digital light processing (DLP) with photopolymer resin. Table 1 lists the parameters used in the printing process.

Table 1. 3D Printing Parameters

Parameter	**Value**
Layer thickness	0.1 mm
Support density	30%
Exposure time	3 s
First layer exposure	40 s
Delay between exposures	10 s

After printing, the mechanical and electronic components—including the camera, battery, and other modules—were assembled. Any issues encountered during assembly were addressed through iterative redesign and reprinting.

The final prototype was evaluated for mechanical integrity, ergonomic fit, and compatibility with electronics. It was also tested for ease of disinfection and liquid ingress resistance. Mechanical strength was verified through load testing by fixing the laryngoscope blade to a rigid surface and applying force to the handle. A successful prototype was defined as one meeting all ergonomic, hygienic, mechanical, and functional requirements under simulated usage conditions.

Findings and Discussion

Electronics Results

The prototype video laryngoscope device, developed as part of this study, relies on multiple electronic components to fulfill its intended functionality. To enable proper interconnection

among these components, several printed circuit boards (PCBs) were designed. The 3D views of the designed PCBs are shown in **Figure 2.**

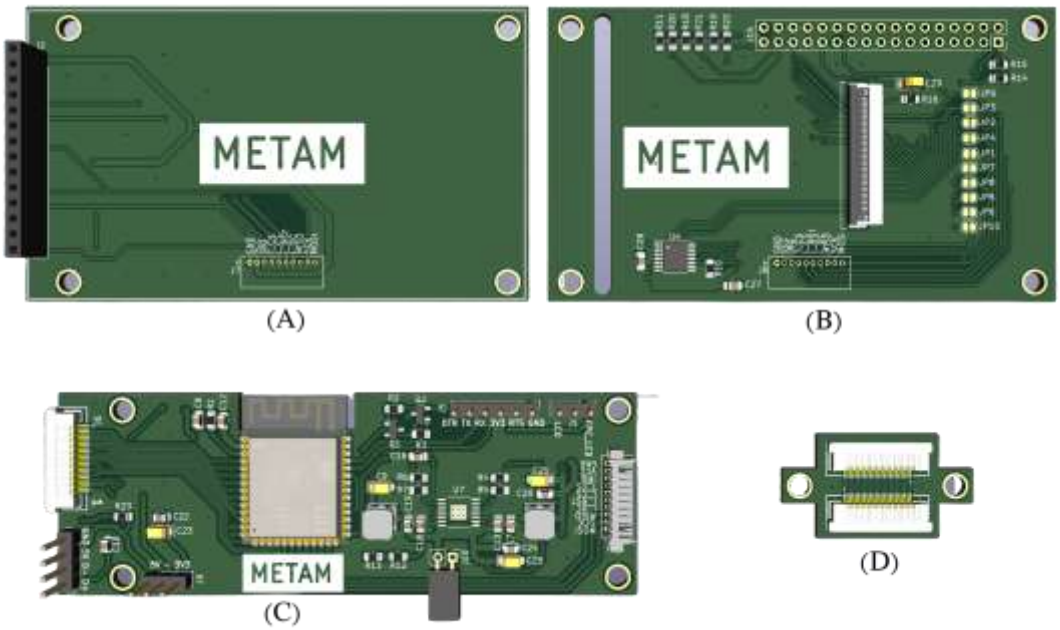
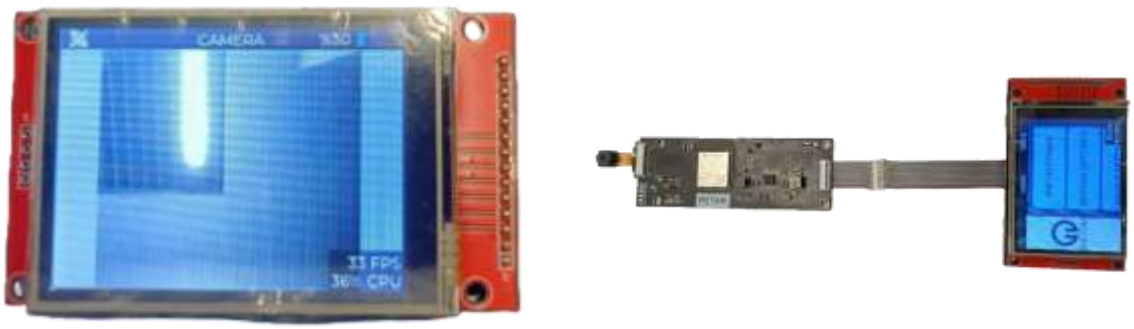


Figure 2. Views of the Electronic Components Designed

As seen in the figure, four separate PCBs were developed for the prototype. **Figure 8A** presents the primary LCD interface board used in the device. **Figure 8B** shows a backup LCD interface, which was not ultimately used as the main LCD interface met performance expectations. **Figure 8C** illustrates the main controller board that integrates the microcontroller, screen and camera connections, voltage regulator, and programming interface. This board supports both USB and Camera Serial Interface (CSI) connections for the camera. For ease of assembly, a USB camera was used in the current prototype. **Figure 8D** shows an extension board designed to enable longer connections for CSI-based cameras, but it was not used in the final setup. The assembled electronic system is presented in **Figure 3**.



(A) (B)

Figure 3. Assembled Electronic Circuits of the Video Laryngoscope Device

In **Figure 3A**, the device's interface and display are shown. The interface was developed using the Light and Versatile Embedded Graphics Library (LVGL), enabling control over Wi-Fi connectivity, remote server configuration, and screen brightness. The 2.8-inch SPI-based display achieves approximately 8 FPS during page transitions, 33 FPS on static pages, and 15 FPS on the camera display page. **Figure 3B** shows the full assembly with all connections in place. The image depicts a setup with a CSI camera, while the screen is connected to the main board via a flexible cable and connector—designed to facilitate integration with the mechanical structure.

The prototype successfully displays real-time camera footage on the built-in screen and simultaneously transmits the image to a remote server via Wi-Fi. This allows external users to access the camera stream live on their devices. In this prototype stage, the server implementation is simplified and does not include features such as user authentication or device switching. A basic mobile-compatible web interface was designed to display the live camera feed, as shown in **Figure 4**.



(A) (B)

Figure 4. View of the Designed Web Interface; (A) Mobile View, **(B)** Desktop View

As shown, the interface includes a dedicated button to focus solely on the camera stream when needed, improving usability on both mobile and desktop devices. The camera captures images in 320×240 pixel resolution in JPEG format. This format was chosen for its reduced data size, allowing faster image acquisition. For on-device display, the image is decompressed and

rendered in raw format, with minimal impact on refresh rate due to efficient decoding in small blocks.

However, wireless transmission introduces challenges due to the 1492-byte Maximum Transmission Unit (MTU) limitation in standard Wi-Fi protocols. To avoid data loss, the JPEG image is segmented, numbered, and transmitted via User Datagram Protocol (UDP) to the remote server. The server reassembles the packets based on sequence numbers, decodes the JPEG using image processing libraries, and scales it to 640×480 resolution for display in the browser.

Mechanical Design and Structural Analysis

The laryngoscope body was designed using SolidWorks, a computer-aided design (CAD) software. The resulting geometry is shown in **Figure 5**. As seen in the figure, the handle section was designed with contours to support the fingers, improving ergonomics and preventing slippage during use. Sufficient internal space was reserved within the body to house all electronic components compactly, contributing to a lightweight and compact final device.

The distal part of the laryngoscope, which enters the patient's mouth, was angled to facilitate the lifting of the epiglottis. Additionally, a cavity was created at the tip of the device to mount the camera. A dedicated channel was also designed, running from the internal electronics compartment to the distal tip, to allow proper cable routing and camera integration.



Figure 5. Laryngoscope Body Design

The detailed placement of the electronic components within the laryngoscope body is presented in **Figure 6**. As illustrated, a dedicated camera channel was included, extending from the internal electronics compartment to the distal end. Battery slots were positioned at the bottom of the handle to power the system, with the control board placed above this section. Power and control buttons, including screen adjustment potentiometers, were positioned at the bottom of the body for easy accessibility during operation.

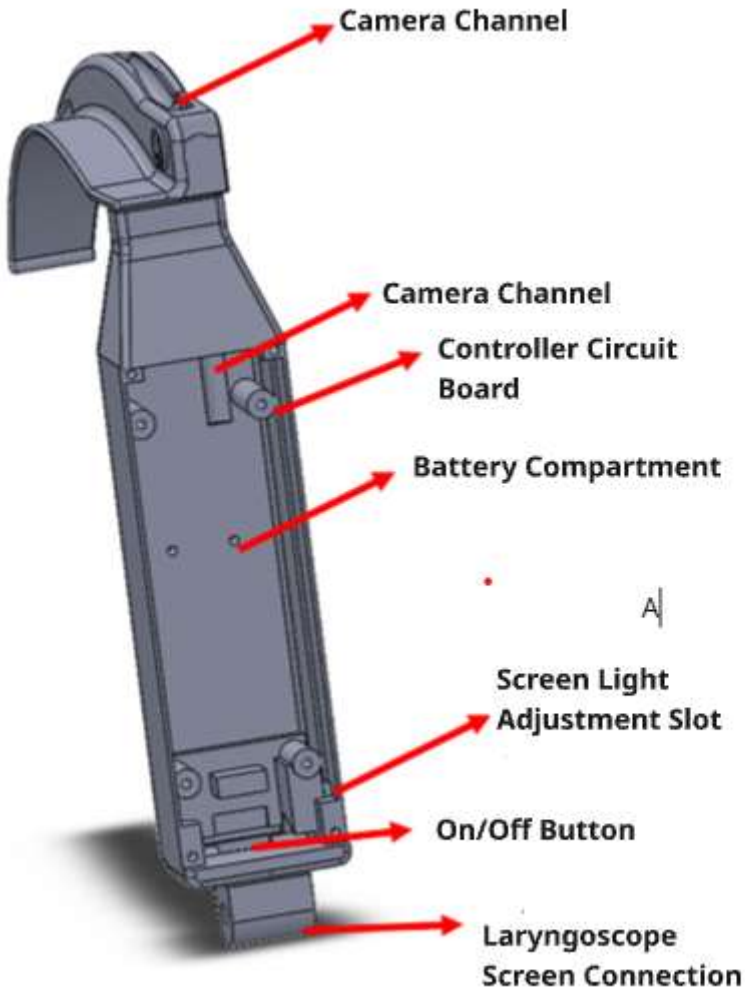


Figure 6. Placement of Electronic Components Within the Laryngoscope Body

The display module, used to present the captured image, was housed in a separate enclosure as shown in **Figure 7**. This housing includes a mounting area for the screen and a channel for routing flat cables externally. Additionally, mechanical protrusions at the base of the enclosure allow it to be connected to the main laryngoscope body.

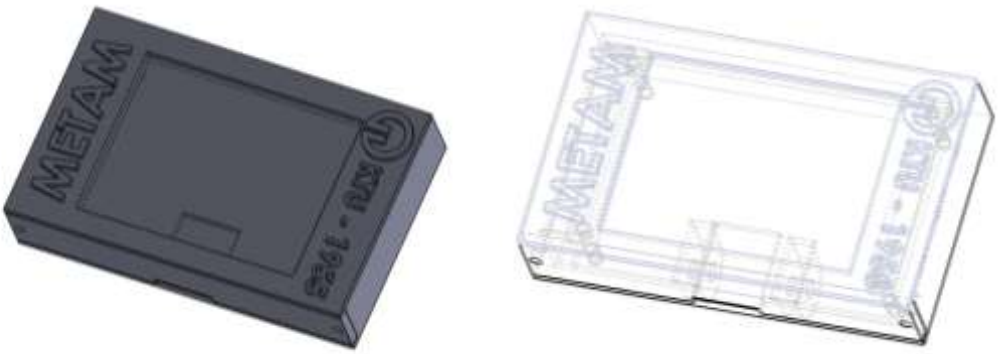


Figure 7. Enclosure for the Laryngoscope Display Module

In the final assembly stage, the laryngoscope and screen housing were integrated, as shown in **Figure 8**. The connection between the screen and the body is articulated, allowing the user to tilt the display according to their viewing angle. This design enables clear visualization regardless of the patient's or clinician's position.

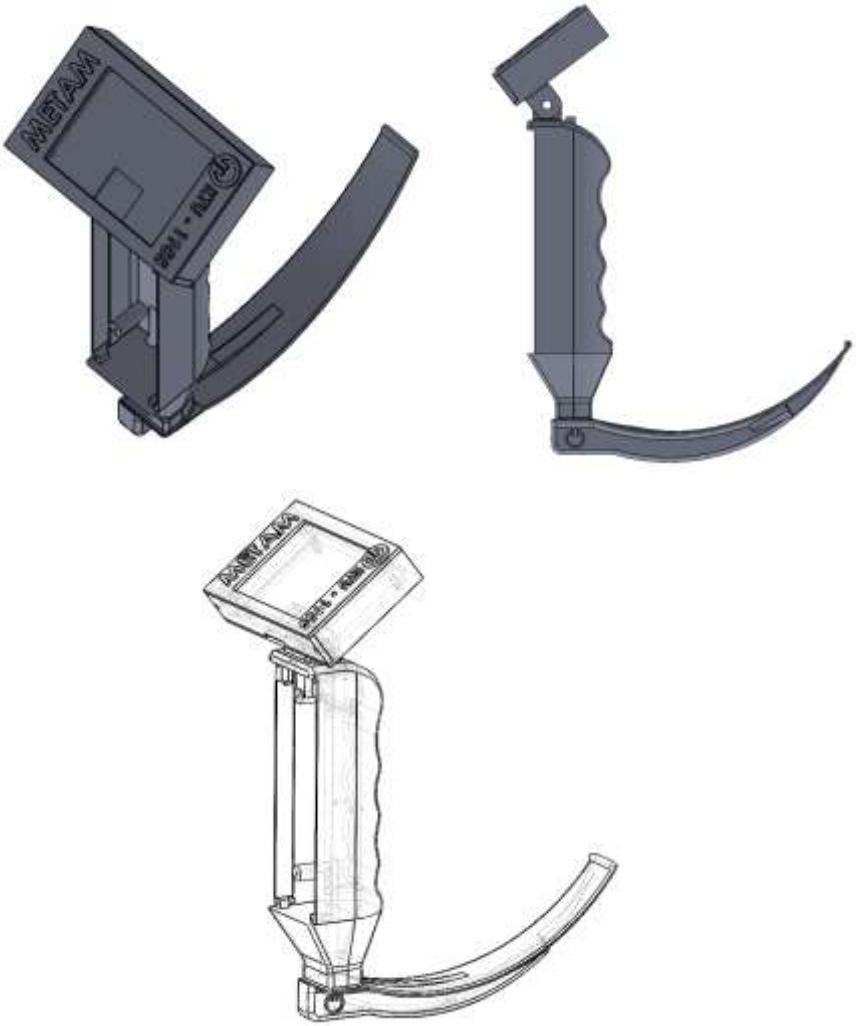


Figure 8. Final Assembly of Laryngoscope Components

To evaluate structural robustness and optimize the design, finite element analysis (FEA) was conducted. The results are presented in **Figure 9**. During simulation, the handle was fixed, and force was applied to the tip of the blade. High stress concentrations were initially observed at the junction of the blade and the main body. Through optimization, these concentrations were significantly reduced. As seen in **Figure 9**, the final design demonstrates low levels of stress, indicating a structurally sound model suitable for practical use.

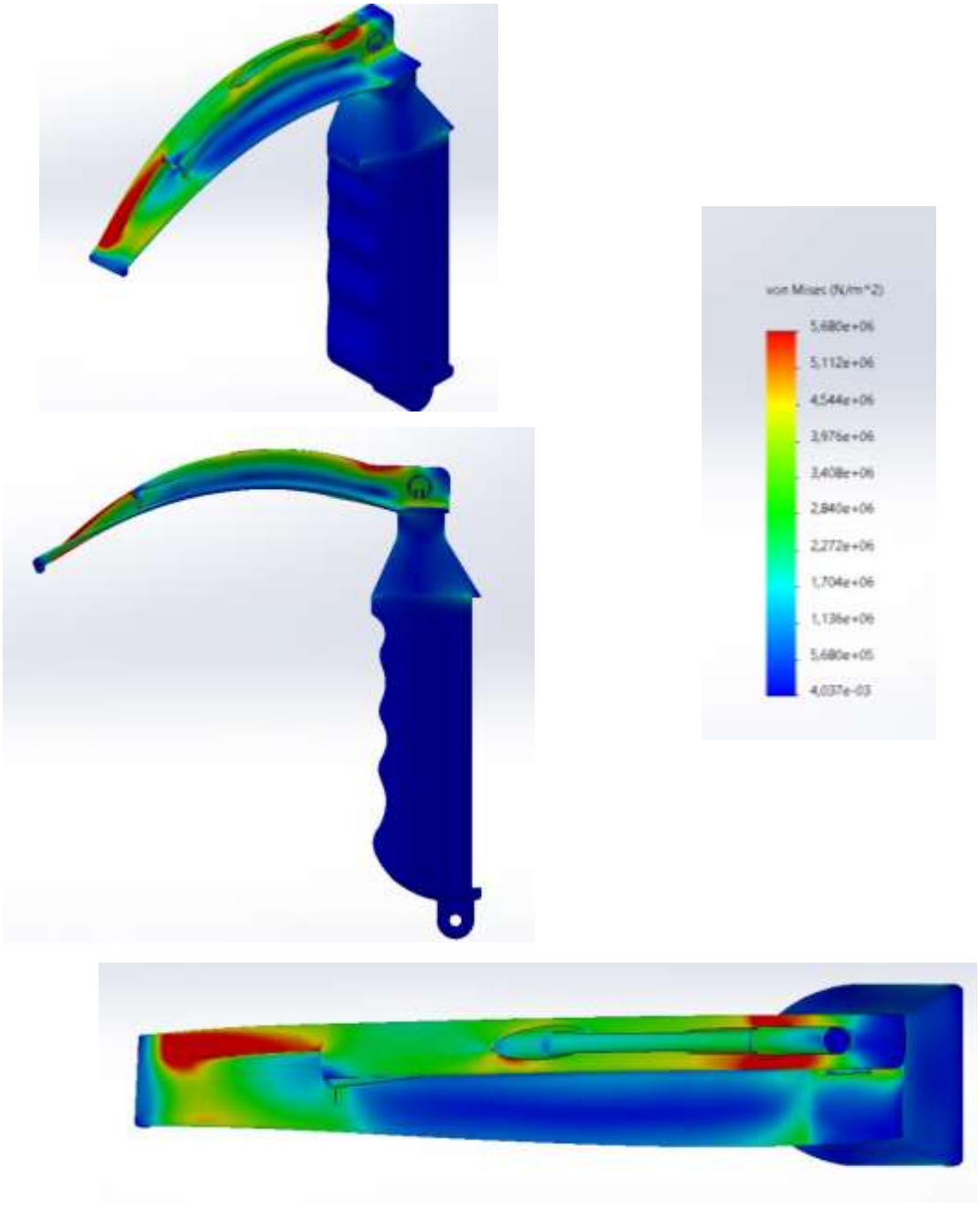


Figure 9. Finite Element Analysis of the Laryngoscope Design

Following the completion of mechanical and electronic fabrication, the components were assembled to form the final video laryngoscope device. Functional tests were conducted on the

assembled prototype, including image quality evaluation, extended runtime testing, and wireless video transmission performance.

Based on the results, the device was observed to operate wirelessly for durations exceeding one hour without interruption. These tests confirm the successful integration of all components and the prototype's capability to perform under realistic conditions. The assembled and tested prototype is shown in **Figure 10**.



Figure 10. Assembled Video Laryngoscope Device During Testing

Conclusions and Recommendations

This study presents the design and development of a portable, wireless, and modular video laryngoscope prototype—an innovative medical device intended for use in endotracheal intubation, a critical application of fiber optic and imaging technologies in modern medicine.

A comprehensive review of existing video laryngoscope models in the literature was conducted, highlighting their respective advantages and limitations. Building upon these insights and addressing gaps in the current state of the art, a new prototype was developed to provide wireless image transmission, modular design flexibility, and enhanced portability. The proposed device aims to improve the speed, accuracy, and safety of intubation procedures.

Furthermore, the inclusion of wireless connectivity supports its use in educational settings, enabling real-time demonstration and reducing the time required for medical personnel training. The prototype developed in this study offers significant advantages for both clinical and instructional use, standing out as a practical and cost-effective innovation.

The widespread adoption of such devices could increase the efficiency of diagnosis and treatment processes, enhance patient safety, and improve clinical success rates. From an

economic standpoint, the device also presents a cost-effective solution that could contribute positively to national healthcare systems.

Future work will focus on conducting clinical trials and long-term usage assessments to further validate the device's effectiveness, durability, and reliability in real-world healthcare environments.

Thanks and Information Note

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PRODUCTION OF HYBRID THERMOPLASTIC COMPOSITES REINFORCED WITH HEMP AND BASALT/CARBON FABRICS FOR AUTOMOTIVE INTERIOR TRIM PANELS AND DETERMINATION OF THEIR MECHANICAL AND THERMAL PROPERTIES

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ABSTRACT

In this study, hybrid thermoplastic composite materials reinforced with hemp and basalt/carbon fabrics were developed for the production of sustainable and environmentally friendly automotive interior trim panels. Within the scope of the project, several trials were conducted using various thermoplastic polymers (polyethylene, PET, and PVC) to identify a suitable matrix polymer compatible with the natural fiber hemp fabric. Preliminary evaluations on samples hot-pressed via the film stacking method revealed that PVC exhibited the best interfacial compatibility with hemp fiber among the tested polymers. Accordingly, further composite production was focused on PVC as the matrix, and experimental studies were conducted at different temperatures and layering configurations.

However, due to the surface characteristics of natural fibers, insufficient bonding between the polymer and the fiber was observed, particularly caused by inadequate wetting between the layers. To address this issue, a chemical surface treatment—silanization—was applied to the fibers.

Based on literature reviews and preliminary experiments, a silane type with high chemical bonding affinity to PVC (VTMS) was identified. A silane solution was prepared and applied to the hemp fabrics. As a result, composite plates containing silane-treated hemp fibers were successfully produced. To further enhance mechanical performance, basalt fibers and basalt mesh layers were incorporated into the structure.

Experimental studies aimed at determining the mechanical and thermal performance of the fabricated composite plates are ongoing. If the results proceed as anticipated, a novel and advanced biocomposite structure will be introduced to the literature.

Keywords: Biocomposite, Hemp Fiber, Thermoplastic Composite, Silane Treatment, Automotive Interior Panel

Introduction

In the automotive industry today, environmental sustainability, energy efficiency, and material recyclability have become fundamental criteria in material selection. In this context, natural fiber-reinforced polymer composites have garnered increasing attention, particularly for non-structural automotive components such as interior trim panels, due to their renewable origins, low density, biodegradability, and environmental benefits (Çavdar, 2016).

Among natural fibers, hemp fiber stands out as an eco-friendly alternative to glass and carbon fibers owing to its high specific strength, modulus of elasticity, low density, and biodegradability (Mohanty et al., 2000; Bledzki & Gassan, 1999). The literature reports that hemp-reinforced composites can be processed compatibly with both thermoplastic and thermoset matrices, and through suitable processing parameters and fiber/matrix arrangements, their mechanical properties can compete with or even surpass those of glass fiber-reinforced composites (Drzal et al., 2004). However, the high moisture absorption and structural heterogeneity of hemp fibers have been identified as significant limiting factors adversely affecting the mechanical performance of composites (Brouwer, 2000).

To overcome these limitations, surface modification techniques such as alkaline treatment, silanization, and acetylation have been developed to improve fiber surface characteristics. These treatments enhance fiber-matrix interfacial adhesion, thereby increasing mechanical strength and simultaneously mitigating dimensional stability problems arising from the hygroscopic nature of natural fibers (Kokta et al., 1990a; Vilay et al., 2008; Gassan & Bledzki, 1997; Valadez-Gonzalez et al., 1999). For example, Dewidar et al. (2012) investigated the effects of different fiber contents and orientations on the mechanical properties of hemp fiber-reinforced PVC composites, demonstrating that a 6.2% fiber content resulted in optimal tensile strength improvement. Moreover, SEM analyses confirmed the positive contribution of fiber-matrix interfacial bonding to mechanical performance.

Interior trim panels in the automotive industry must meet multiple criteria including lightness, mechanical strength, dimensional stability, aesthetic quality, acoustic performance, and environmental sustainability (Al-Oqla & Omari, 2018; Zaini et al., 2022). Among thermoplastics, poly(vinyl chloride) (PVC) is preferred due to its low cost, chemical resistance, recyclability, and flame retardant properties (Şeker, 1999).

It has been reported that hemp fiber-reinforced PVC composites exhibit increased tensile strength and stiffness but decreased ductility. Additionally, dimensional stability issues caused by the hygroscopic nature of natural fibers can be alleviated by surface modifications (Mohanty et al., 2000).

Aesthetic expectations within vehicle interiors are met through surface texture, gloss, and color uniformity, while acoustic performance is enhanced by using multilayered and porous structures (Kim et al., 2018; Kumar et al., 2019). Furthermore, automotive materials must ensure environmental and health safety by exhibiting low volatile organic compound (VOC) emissions and flame retardant capabilities (Javadi et al., 2019).

The application of natural fiber-reinforced composites in the automotive sector has been adopted by major manufacturers such as BMW, Audi, Ford, Volvo, and Mercedes-Benz, resulting in significant vehicle weight reduction and consequently lowered fuel consumption and CO_2 emissions. These biocomposites play a critical role in meeting the European Union's 95 g CO_2/km emission limit implemented in 2020 (Avcı, 2021; Çavdar, 2016).

In conclusion, natural fiber-reinforced composites stand among the promising future material solutions in the automotive industry, balancing environmental sustainability with mechanical performance. When used in combination with recyclable thermoplastics like PVC, they provide advantages in lightweighting and durability for interior trim panels. Therefore, optimizing fiber content, appropriate fiber orientation, and effective surface modification techniques is essential to maximize performance and support sustainability goals.

Materials and Methods

This study focuses on the production and characterization of polyvinyl chloride (PVC) matrix composites reinforced with both natural and synthetic fibers. The primary objective is to enhance the structural integrity and mechanical performance of the composites by optimizing fiber-matrix interfacial interactions.

1. Materials

All materials used for composite production were cut into 20 cm × 20 cm square sheets.

Matrix Material: PVC film was employed as the polymer matrix, serving as the primary binding phase. Its thin film form was selected to ensure uniform fiber impregnation and efficient load transfer.
Natural Reinforcement Fiber: Hemp fiber fabrics were selected as reinforcement due to their lightweight nature, environmental sustainability, and inherent mechanical properties. Owing to their high hydroxyl (-OH) content and moisture absorption tendency, surface treatments were applied to mitigate water uptake.

Synthetic Reinforcement Fibers (for Hybrid Structures):

Carbon Fiber and Carbon Mesh: Used in hybrid samples to enhance mechanical strength and stiffness.

Basalt Fiber and Basalt Mesh: Incorporated as sustainable alternatives to carbon and glass fibers, offering superior thermal stability, chemical resistance, and mechanical properties. Silanization Agents: A blend of silicone oil, powdered resin (as a binding agent), and silane was used to improve fiber-matrix adhesion.

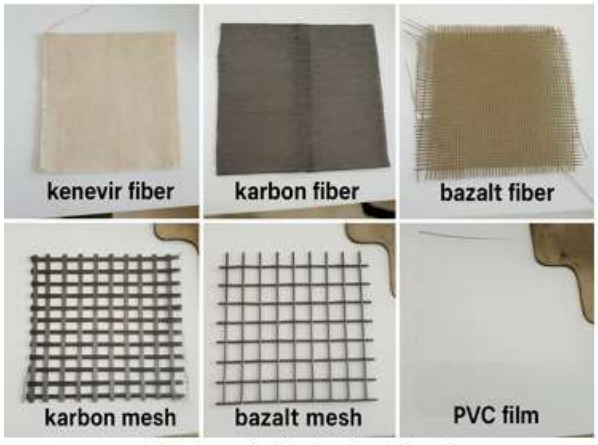


Figure 1. Fabrics Used



Figure 2. Silane Materials

2. Material Preparation and Surface Treatment

To reduce the moisture absorption tendency and improve the interfacial compatibility between hemp fibers and the PVC matrix, pre-treatments and silanization were applied to the hemp fabrics. Prior to silanization, hemp fabrics were preheated at 190 °C for 5 minutes to eliminate residual moisture.



Silanization Process: A detailed silanization protocol was followed to enhance surface wettability and fiber-matrix bonding. First, 60 g of silicone oil was combined with 6.66 g of powdered resin and stirred using a magnetic stirrer at 300 rpm and 30 °C until a homogeneous solution was achieved. Subsequently, 1.3 g of silane was precisely weighed and added to the mixture, which was stirred further to ensure full homogenization. The silane solution was then uniformly applied to the preheated hemp fabric using a brush, as illustrated in Figure 2.1. This treatment aimed to enable covalent bonding between the silane molecules and hydroxyl groups on the fiber surface, while supporting adhesion between the silicone/resin matrix and the modified fiber surface.

Figure 3. Silane Mixture

3. Composite Specimen Fabrication

Composite samples were produced via a hot-press molding process using optimized manufacturing parameters. Preliminary studies and systematic optimization trials identified the ideal conditions for ensuring homogeneous matrix infiltration and improved interfacial bonding. To prevent local dry spots, which were observed when hemp layers were increased, a strategy was adopted whereby two layers of PVC film were inserted between each hemp fiber layer.

This ensured complete and uniform resin impregnation, significantly improving structural cohesion and interfacial strength.

Optimized Process Parameters:

PVC Film Configuration: A configuration of 8 PVC films and 3 hemp layers was determined to provide the optimal balance of wetting, thickness, and mechanical integrity. Temperature: A pressing temperature range of 180 °C to 190 °C was found to be ideal for achieving structural consistency and visual quality without thermal degradation. Pressure Sequence: A combination of 5 tons of hot press (10 minutes) followed by 7–10 tons of cold pressing (5 minutes each) yielded excellent mechanical properties and robust interfacial bonding.

Sample Configurations: Five different sample groups were fabricated, each comprising 5 reinforcement layers separated by two layers of PVC film, totaling 12 PVC layers per sample:

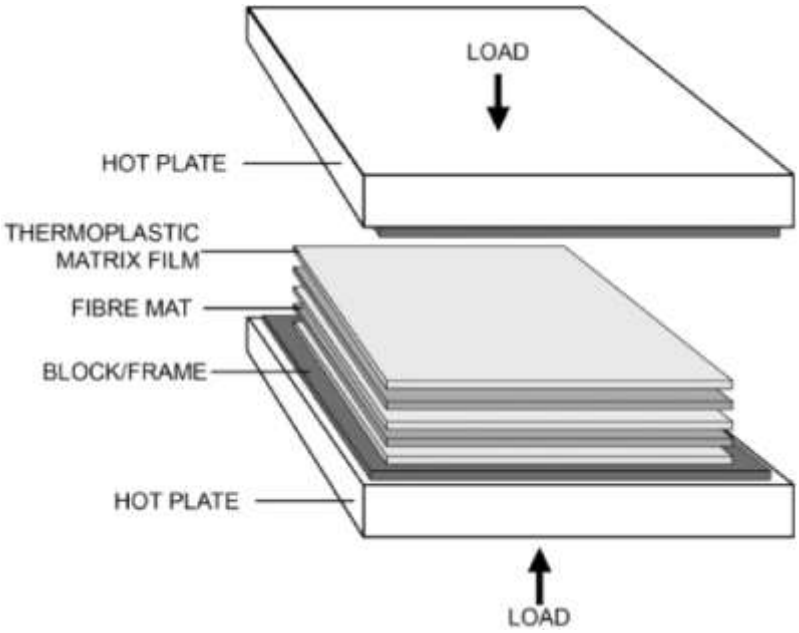


Figure 4. Film Stacking Huerta-Cardoso et al., 2022

Sample 1: Fully hemp-reinforced composite (5 hemp layers)

Sample 2: Hybrid composite with hemp and carbon fibers (3 hemp, 2 carbon)

Sample 3: Hybrid composite with hemp and carbon mesh (3 hemp, 2 carbon mesh)

Sample 4: Hybrid composite with hemp and basalt fibers (3 hemp, 2 basalt)

Sample 5: Hybrid composite with hemp and basalt mesh (3 hemp, 2 basalt mesh)

Pressing Procedure: Prepared sample stacks were first hot-pressed at 5 tons for 10 minutes. Subsequently, cold pressing was applied in two stages: 7 tons for 5 minutes followed by 10 tons for another 5 minutes.

Upon completion, the composite laminates were removed from the press and set aside for further processing.



Figure 5. Hot Press



Figure 6. Cold Press

4. Sample Cutting and Characterization Preparation

The proper sizing and shaping of composite laminates for testing is critical for data accuracy and repeatability.

Rough Cutting: Initial rough cutting of composite laminates was performed using a circular saw at the Forest Industry Engineering Education and Practice Workshop. A dry cutting technique was used to minimize fiber pull-out, fraying, and delamination. To stabilize the process, the composite laminates were clamped between two wooden plates during cutting, reducing direct impact from the saw blade (Campbell, 2004; Hull & Clyne, 1996).

Precision Cutting: Rough-cut composites were further refined using a wet abrasive cut-off machine to obtain test samples with appropriate dimensions and surface quality. Continuous coolant flow was used to minimize frictional heating and prevent thermal damage. This process ensured that specimens met the dimensional and surface quality requirements specified by international standards for optical microscopy, scanning electron microscopy (SEM), and density measurements (Metals Handbook, 1986).

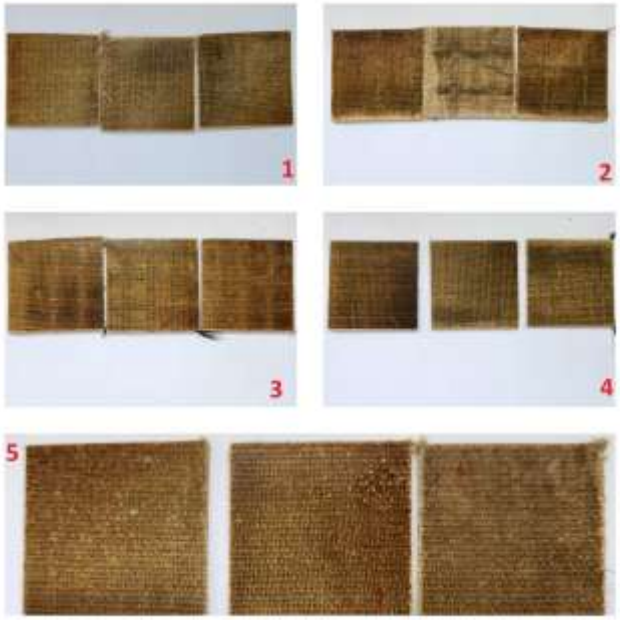


Figure 7. Precision Cut Samples

Findings and Discussion

Tensile Test

Tensile tests conducted in accordance with ASTM D638 revealed the influence of different fiber types and configurations on the mechanical properties of composite materials. The results clearly indicate that reinforcement type, fiber form, and fiber-matrix interaction play a critical role in determining both strength and deformation behavior.

The highest tensile strength, 88.00 MPa, was achieved with the basalt fiber-reinforced composite. This highlights basalt's high intrinsic strength and its ability to form an effective interfacial bond with the matrix. The hemp-basalt hybrid composite not only exhibited considerable strength but also demonstrated a prolonged elastic deformation range, indicating balanced mechanical performance. The synergy between the two fiber types enhanced both strength and energy absorption capacity.

The mechanical behavior of carbon-reinforced composites varied significantly depending on the form of the fiber. The sample containing carbon mesh showed substantial strength (64.73 MPa), but its low deformation tolerance led to brittle failure. In contrast, the carbon fabric-reinforced composite exhibited both lower tensile strength (34.23 MPa) and limited elongation, likely due to inadequate fiber-matrix bonding.

In the case of natural fiber composites, ductility emerged as a key characteristic. The sample reinforced solely with hemp fibers showed relatively low strength (39.23 MPa) but demonstrated an extended elongation region, indicative of high deformation capacity. This behavior was even more pronounced in the sample with increased hemp fiber content, which achieved moderate strength and high ductility.

These results underscore the contribution of natural fibers' flexibility to the overall toughness of the composite system.

In summary, while basalt fibers stood out for their strength contribution, hybrid hemp-basalt structures offered well-balanced and versatile mechanical performance. The effectiveness of carbon reinforcements was found to be highly dependent on fiber form and interfacial bonding, whereas natural fibers provided notable advantages in terms of ductility and deformation tolerance.

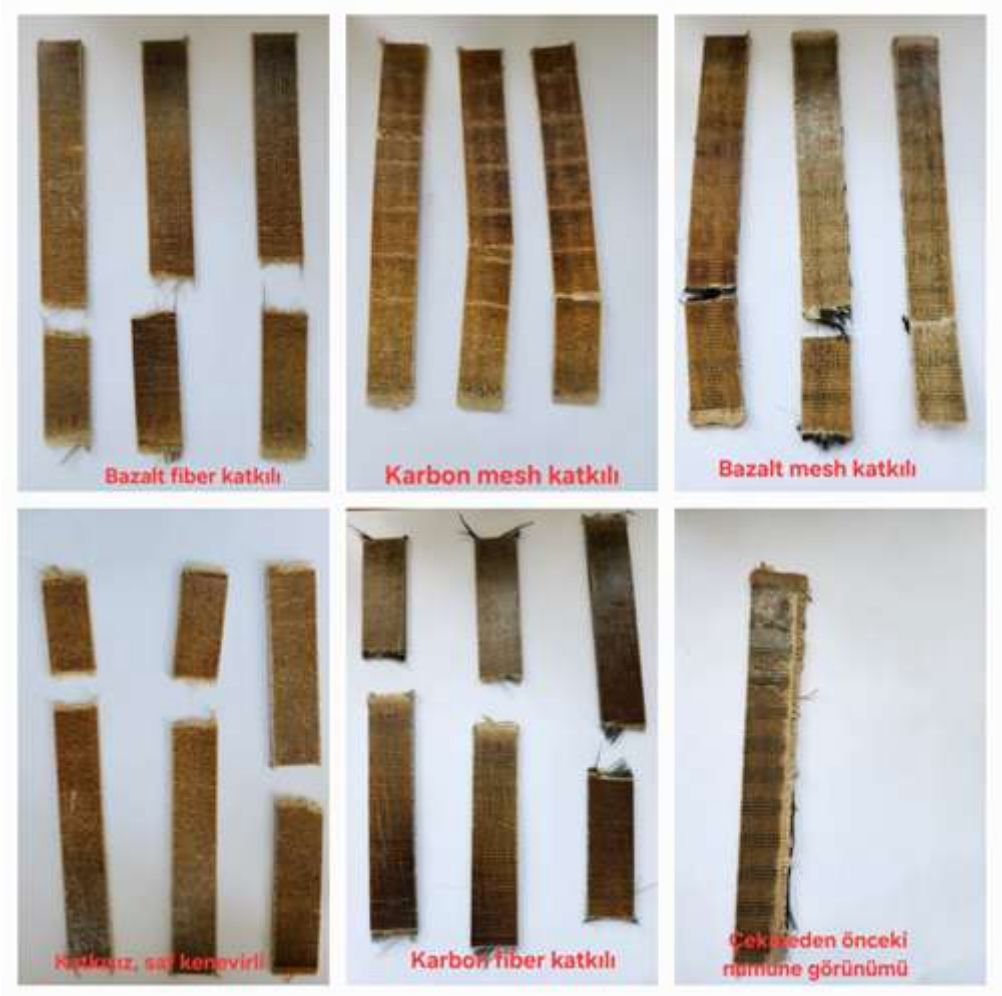


Figure 8. Condition of Samples After Tensile

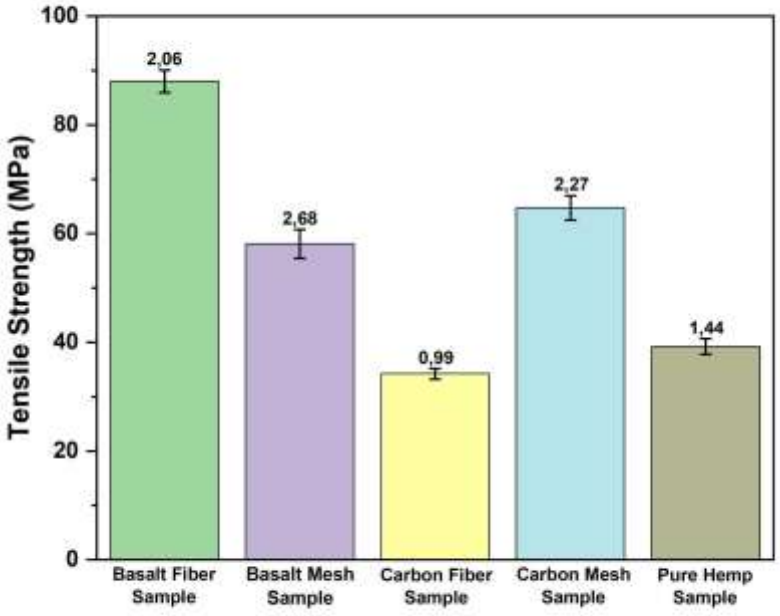


Table 1. Tensile Strength Average Ranking

Three Point Bend Test

The effects of different fiber reinforcement types (basalt, carbon, hemp) and forms (fabric, mesh) on the interlaminar shear strength of polymer composites were experimentally investigated. The findings indicate that both the chemical structure and geometry of the reinforcement material significantly influence shear strength.

The basalt fabric-reinforced composite exhibited the highest shear strength at 232.5 MPa. This can be attributed to the high intrinsic mechanical strength of basalt fibers and the homogeneous and extensive surface contact provided by the fabric form, which enhances load transfer efficiency. The fabric structure plays a critical role in achieving optimal fiber alignment, thereby minimizing delamination and interfacial damage. Basalt mesh, with a shear strength of 187.5 MPa, ranked second, confirming the inherent shear strength of basalt fibers, although it lagged slightly behind the fabric form due to its relatively reduced surface contact area.

In carbon-reinforced composites, the form of the reinforcement had a notable effect on shear strength. Carbon mesh (141.4 MPa) showed significantly higher shear strength than carbon fabric (103.072 MPa). Contrary to expectations, carbon fabric exhibited the lowest shear strength, which is associated with the brittle nature of carbon fibers, difficulties in matrix penetration, and insufficient interfacial cohesion. The more permeable structure of the mesh form facilitated better matrix infiltration between the fibers and improved distribution of shear forces.

The natural hemp-reinforced material demonstrated a moderate shear strength of 147.2 MPa. While this value was higher than both carbon fabric and mesh, it was still lower than that of basalt reinforcements. Although hemp fibers offer environmental sustainability advantages due

to their natural origin, limitations such as structural inhomogeneity and a tendency to absorb moisture can restrict their strength.

In conclusion, this study shows that the interlaminar shear strength of composite materials varies significantly depending on both the type and form of the fiber reinforcement. Reinforcements such as basalt fabric, which provide high strength and good integration with the matrix, are particularly critical for applications requiring high structural performance and durability. The findings highlight the vital role of reinforcement selection and form optimization in determining the final mechanical performance of composite materials.

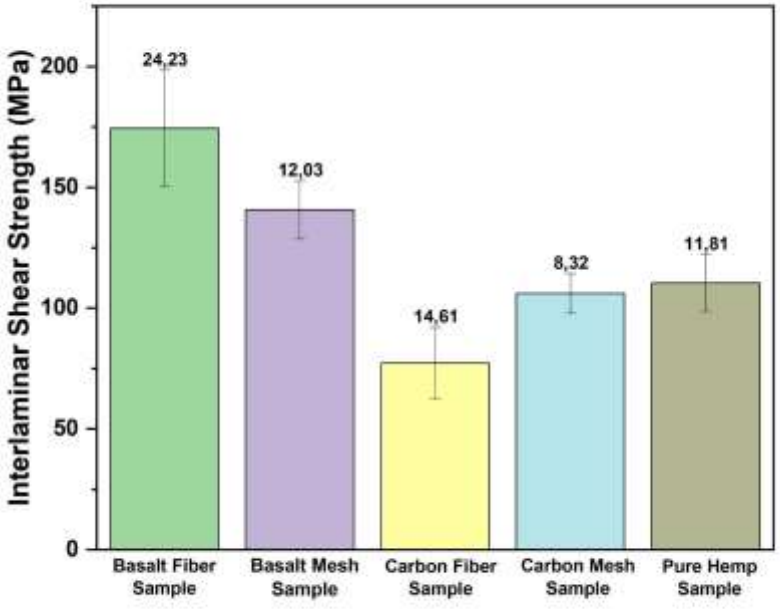


Table 2. İnterlaminar Shear Strenght

Thermal Conductivity Results and Interpretation

This section evaluates the thermal conductivity (λ) values of five composite groups reinforced with different materials. Low thermal conductivity indicates good thermal insulation performance. For each group, the mean values and standard deviations from three separate measurements were analyzed.

Basalt Mesh Composite (Group 2): Exhibited the lowest thermal conductivity with an average of 0.0309 W/m·K, indicating the best thermal insulation performance.

The extremely low standard deviation (0.0001) confirms high consistency in the measurements and structural homogeneity of the sample.

Carbon Fiber Composite (Group 4): With an average thermal conductivity of 0.0479 W/m·K, it showed the second-best insulation performance after the basalt mesh composite. The standard deviation of 0.0001 supports the uniformity and consistency of the material structure.

Pure Hemp Composite (Group 5): Recorded an average thermal conductivity of 0.0524 W/m·K, with a standard deviation of 0.0002. The performance of pure hemp falls between that

of basalt fiber and carbon fiber composites, with good consistency observed across measurements.

Basalt Fiber Composite (Group 1): Had an average thermal conductivity of 0.0555 W/m·K. The low standard deviation (0.0002) indicates reliable measurements and consistent thermal performance across the sample.

Carbon Mesh Composite (Group 3): Displayed the highest average thermal conductivity at 0.0610 W/m·K, suggesting the lowest insulation performance among all groups. The significantly higher standard deviation (0.0013) points to structural heterogeneity or variability in the measurements.

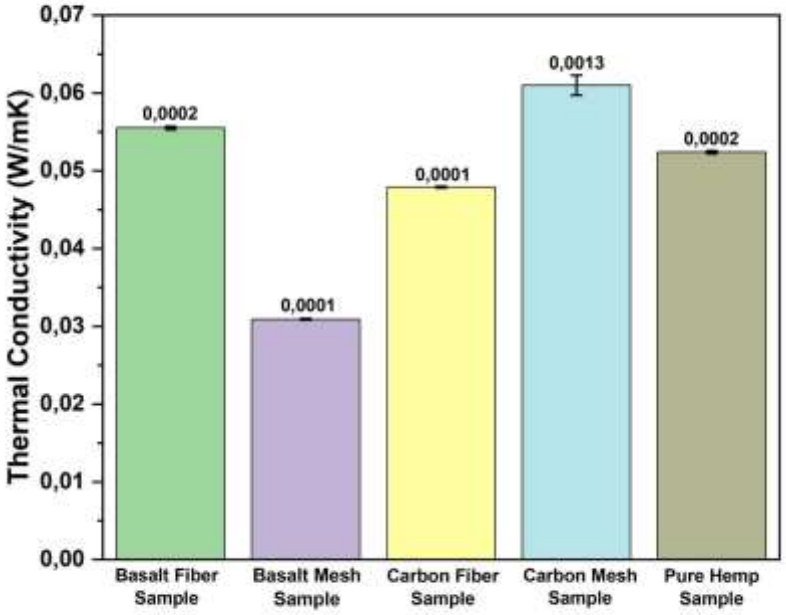


Table 3. Thermal Conductivitiy

Density Results and Interpretation

The density values (g/cm³) of the composite samples revealed the effects of different reinforcement materials on the overall composite structure. The average density and standard deviation for each sample group were determined.

Basalt Fiber Composite (Sample 2): With an average density of 1.3723 g/cm³, it was the second densest composite. The high density of basalt fibers (~2.7 g/cm³) and their uniform distribution significantly increased the overall density of the composite. The low standard deviation (0.0121 g/cm³) indicates a high degree of uniformity during the manufacturing process.

Carbon Fiber Composite (Sample 5): Exhibited a higher density (1.3159 g/cm³) compared to other carbon-reinforced samples. This can be attributed to the continuous and dense structure of the carbon fiber fabric, which may have integrated more effectively with the matrix, leaving fewer voids and contributing more mass to the composite.

Basalt Mesh Composite (Sample 3): Had an average density of 1.2831 g/cm³. This lower value, compared to continuous basalt fibers, may result from the mesh form contributing less to the overall density and potentially creating more voids within the matrix.

Pure Hemp Composite (Sample 6): Containing only hemp fibers and PVC film, this sample had a moderate average density of 1.2694 g/cm³. This reflects the relatively low densities of hemp fibers and PVC. The low standard deviation (0.0238 g/cm³) indicates good reproducibility in the manufacturing process.

Carbon Mesh Composite (Sample 4): Presented the lowest density value with an average of 1.2412 g/cm³. The result aligns with carbon's lower intrinsic density (~1.8 g/cm³) compared to basalt. The very low standard deviation (0.0077 g/cm³) suggests that this structure was also stably positioned during fabrication.

In general, continuous fiber forms of basalt and carbon increased the overall density of the composites, while mesh reinforcements resulted in lower density values.

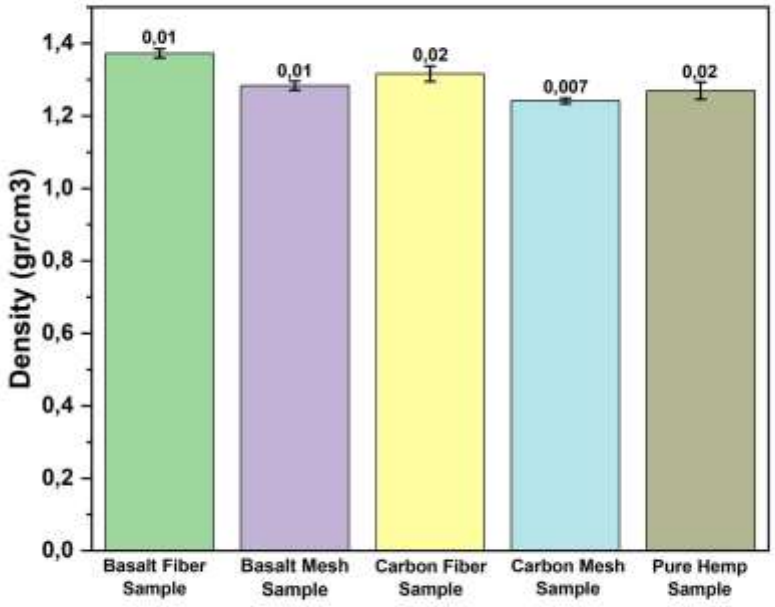


Table 4. Density

Optical Review

Optical microscopic examinations and microstructural analyses were conducted to evaluate the wettability behavior at the fiber–matrix interfaces and to identify structural defects in the samples. The findings revealed the critical influence of reinforcement materials and the manufacturing process on wettability and overall composite integrity.



Figure 9. Optical Examination Samples

Wettability of Hemp Fibers: Surface modification with a silane agent partially improved the wettability of hemp fibers within the matrix. The silane coating enhanced the chemical compatibility of the fiber surface, improving fiber–matrix adhesion and promoting better interaction with the resin. However, full impregnation of the fibers was not achieved, and some areas still exhibited insufficient bonding. Although partial wetting reduces the risk of fiber pull-out under mechanical loading, it limits the composite's full strength potential. (Microscopic images of the hemp/PVC composite indicate that silane treatment improved adhesion at the fiber–matrix interface to some extent, though ideal wetting conditions were not achieved. Unwetted regions on fiber bundles and surfaces, along with the resulting voids, are considered critical microstructural defects that restrict the composite's mechanical performance.)

Wettability of Basalt Fibers: In the basalt fiber regions, the matrix was observed to spread homogeneously across the fiber surfaces, effectively encapsulating them. This indicates that the dense and uniform structure of basalt fibers allows high interfacial compatibility with the PVC matrix. The sample demonstrated more stable and homogeneous wetting behavior for basalt fibers.

Wettability of Basalt Mesh: Microstructural images showed that the basalt mesh structure was completely coated with resin. However, it remains uncertain whether this coating resulted from pre-impregnation of the mesh with resin or from effective wetting by the PVC matrix. Further advanced analyses (e.g., SEM examination, spectroscopy) are needed to make a definitive assessment.

Wettability of Carbon Mesh: In the carbon mesh region, the fibers exhibited a more organized and dense distribution within the matrix and showed strong interaction with the resin. This behavior can be attributed to the high surface energy of carbon fibers, which promotes good mechanical interlocking with the PVC matrix. The fine fiber structure of the carbon mesh also facilitates more effective resin penetration and minimizes void formation.

Wettability of Carbon Fibers: Microstructural analysis revealed that the thick, continuous structure of carbon fibers hindered effective wetting by the PVC matrix. Microscopic images showed that the resin did not fully encapsulate the fiber surfaces and that sufficient interfacial

adhesion was lacking. The dense carbon fibers restrict resin penetration, increasing the risk of weak bonding and potential delamination.

Void and Porosity Formation: Voids and gaps observed in the composite structure were likely caused by air entrapment during manufacturing, inadequate resin flow, or cutting-induced defects. These microstructural flaws weaken fiber–matrix adhesion, lead to stress concentrations, and negatively affect the composite's mechanical properties (particularly impact resistance, fatigue life, and tensile strength). In particular, the insufficient wetting of thick carbon fibers and unimpregnated carbon mesh surfaces contributed to the formation of micropores.

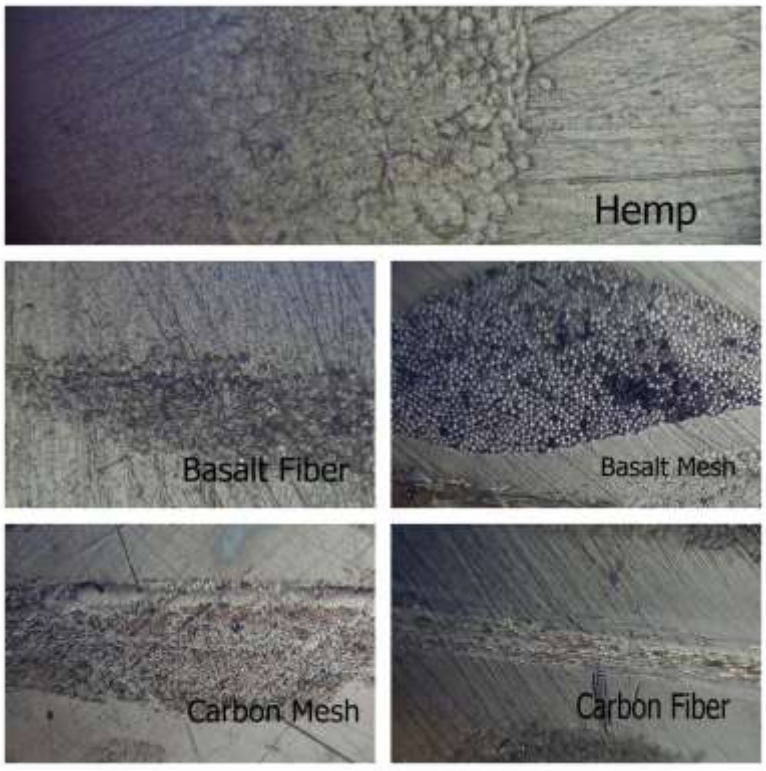


Figure 10. Optic Result

Overall, optical microscopy clearly indicated that basalt fibers provided the best wetting performance. Their continuous and uniform contact with the matrix reflects excellent interfacial compatibility. In contrast, carbon fiber fabric showed the lowest degree of wettability. Although the silane treatment significantly improved the wettability of natural fibers, complete wetting has not yet been achieved. These findings suggest that both hemp and carbon reinforcements were distributed effectively within the PVC matrix, and that acceptable interfacial integrity was achieved with proper surface treatments. However, eliminating process-related defects and ensuring complete wetting are critical for achieving optimal performance.

Conclusion and Recommendations

In this study, hybrid thermoplastic composites reinforced with natural (hemp) and synthetic (basalt and carbon) fibers were successfully fabricated using polyvinyl chloride (PVC) as the matrix material. The primary goal was to develop environmentally friendly, recyclable, and mechanically robust materials suitable for automotive interior trim applications. Surface modification of hemp fibers via silanization notably improved fiber–matrix compatibility, although complete wetting and interfacial bonding were not fully achieved. Among all

reinforcements, basalt fiber-reinforced composites demonstrated the highest tensile strength and superior wettability, indicating excellent compatibility with the PVC matrix. Hybrid configurations, especially those combining hemp and basalt fibers, offered balanced mechanical performance and improved energy absorption capabilities.

Thermal conductivity analyses revealed that composites containing basalt mesh exhibited the best thermal insulation properties, while carbon mesh composites showed higher thermal conductivity values, suggesting lower insulation efficiency.

Density measurements supported the conclusion that reinforcement type and form significantly influence the overall composite structure, with continuous fiber forms contributing to higher density values. Optical microscopy confirmed that basalt and silane-treated hemp fibers facilitated better resin penetration compared to untreated or thick carbon fiber fabrics.

In light of these findings, the following recommendations are proposed for future studies and industrial applications:

1. Enhanced Surface Treatment: The silanization process can be optimized further to achieve more uniform and complete fiber wetting. Additional surface modification techniques, such as plasma or enzymatic treatments, may be explored.
2. Hybrid Design Optimization: Fiber content, layering order, and mesh integration strategies should be fine-tuned to exploit the synergistic benefits of natural and synthetic reinforcements.
3. Advanced Characterization: Further analysis using scanning electron microscopy (SEM), dynamic mechanical analysis (DMA), and long-term aging tests can provide deeper insight into interfacial behavior and long-term performance.
4. Sustainability Assessment: Life cycle analysis (LCA) and recyclability studies should be conducted to quantify the environmental impact and potential advantages of these biocomposites over conventional materials.
5. Process Improvements: Improvements in resin infiltration and lamination techniques may help reduce void content and enhance mechanical integrity, particularly in thick or multilayered configurations.

In conclusion, hybrid thermoplastic composites developed in this study present a promising solution for sustainable and high-performance automotive applications. With further optimization, these materials have the potential to replace conventional synthetic composites and contribute to the industry's decarbonization and recyclability goals.

Thanks and Information Note

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In addition, we extend our appreciation to all academic and technical stakeholders who contributed to the scientific quality of the project through their guidance, provision of materials, and support in experimental measurements during the course of the study.

The data presented in this paper are based on experimental findings obtained within the scope of an ongoing master's thesis. The related studies are still in progress, and the final results are planned to be published comprehensively upon completion.

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NEUROSCIENTIFIC FOUNDATIONS OF FINANCIAL DECISION-MAKING: A NEUROACCOUNTING APPROACH

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ABSTRACT

This study presents a theoretical framework for neuroaccounting, an interdisciplinary approach that investigates the neural mechanisms underlying decision-making processes in the accounting domain, thereby challenging the assumptions of classical rationality. Rooted in cognitive neuroscience, neuroaccounting aims to elucidate the emotional and cognitive underpinnings of financial behavior at both individual and institutional levels. Specifically, the involvement of brain regions such as the prefrontal cortex, amygdala, and anterior cingulate cortex in accounting-related judgments provides a neuroscientific dimension to behavioral accounting and finance theories. This paper delineates the conceptual foundations and interdisciplinary scope of neuroaccounting, reviews the current literature, and evaluates the methodologies and experimental paradigms employed in the field. Additionally, the practical implications and ethical concerns associated with neuroaccounting are critically examined. The study concludes by discussing the potential contributions of neuroaccounting to accounting science and proposing avenues for future research.

Keywords: Neuroaccounting, Neuroscience, Financial Decision-Making, Behavioral Accounting, Neuroscientific Approaches in Finance

Giriş

Finansal karar alma süreçleri, geleneksel iktisat kuramlarında rasyonel birey varsayımı üzerinden açıklansa da son yıllarda yapılan çalışmalar bireylerin kararlarında duygusal, bilişsel ve nörolojik faktörlerin de etkili olduğunu ortaya koymuştur. Bu bağlamda, davranışsal iktisat ile nörobilim disiplinlerinin birleştiği yeni bir alan olan "nörofinans" (neurofinance), finansal kararların arka planındaki sinirsel süreçleri anlamaya yönelik katkılar sunmaktadır. Bu alan altında gelişen "nöromuhasebe" (neuroaccounting) ise, bireylerin muhasebe verilerini nasıl algıladığı, işlediği ve kararlarını nasıl oluşturduğu konularında biyo-nörolojik temelli bir analiz imkânı sağlamaktadır.

Nöromuhasebe yaklaşımı, klasik muhasebe teorilerinden farklı olarak, sadece sayısal verilerin sunumu ile değil, bu verilerin insanlar üzerindeki psikolojik ve nörolojik etkileri ile de ilgilenmektedir (Dickhaut vd., 2010). Beyin yapılarının finansal kararları hangi mekanizmalarla etkilediğine dair bulgular, muhasebe verilerinin şekillendirilmesinde ve yorumlanmasında alternatif bir perspektif sunmaktadır. Bu perspektif, finansal tabloların sunum biçiminden, yönetici kararlarına ve denetim süreçlerine kadar geniş bir uygulama alanına sahiptir.

Nörobilimsel temelli karar alma modelleri, muhasebe bilgilerinin rasyonel beklentiler çerçevesinde değil, çoğu zaman bilişsel kısıtlar ve duygusal önyargılarla şekillendiğini ortaya koymuştur. Örneğin, zarardan kaçınma (“loss aversion”), aşırı özgüven (“overconfidence”) ya da çerçevelendirme (“framing”) etkisi gibi bilişsel yanlılıklar, finansal verilerin algılanması ve kullanımında belirleyici olabilmektedir (Kahneman & Tversky, 1979). Bu şekilde, finansal karar alma süreci sadece bilgi ile değil, bilginin sunumu, algılanması ve biyo-nörolojik şartlarla da yoğun şekilde ilintilidir.

Bu çalışma, muhasebe ve finans alanında yeni sayılabilecek bir disiplin olan nöromuhasebe kavramının teorik temellerini tartışmayı, ilgili nörobilimsel bulgularla ilişkilendirerek finansal karar alma modellerine etkilerini ortaya koymayı amaçlamaktadır. Özellikle bireylerin finansal verileri yorumlama biçimleri ile bu yorumlara dayalı kararların nörolojik temelini anlamak, daha sağlıklı raporlama standartlarının ve daha etkili denetim mekanizmalarının geliştirilmesine katkı sunabilecektir.

Nörobilim ve Karar Alma Mekanizmaları

Finansal karar alma davranışı yalnızca ekonomik değişkenlerin değil, bireyin beyin yapısının ve nörolojik işleyişinin bir sonucudur. Bu bölümde, ekonomik karar süreçlerinin beyindeki işleyişini anlamak amacıyla dört temel başlık üzerinde durulacaktır: Beyin fonksiyonları ve ekonomik davranış, prefrontal korteksin rolü, duyguların karar süreçlerindeki etkisi ile risk algısının nörolojik temelleri.

Beyin Fonksiyonları ve Ekonomik Davranış

Günümüzde karar alma süreçlerinin incelenmesinde nörobilimsel yaklaşımlar oldukça önem kazanmıştır. İnsan beyni, çeşitli bilişsel fonksiyonlar aracılığıyla ekonomik kararları şekillendirir. Özellikle dikkat, hafıza, öğrenme ve duygusal düzenleme gibi süreçler, bir bireyin karşısındaki ekonomik seçeneği nasıl değerlendireceğini belirler. Örneğin, beyin ödül merkezleri olan ventral striatum ve orbitofrontal korteks, bireylerin gelecekteki ödüllere dair beklentilerini işler ve bu bilgiler karar alma sürecine dahil edilir (Glimcher & Fehr, 2014).

Ekonomik kararlar genellikle "kâr-maliyet" analizi gibi görünse de aslında bu süreçler esnasında beyin, önceki deneyimlerinden gelen verileri, belirsizlik koşullarını ve sosyal faktörleri değerlendirerek sonuca ulaşır. Özellikle nöronal aktivitenin arttığı bazı bölgelerin

(örneğin anterior singulat korteks) hata tahminleri ve alternatifler arasında seçim yapma süreçlerinde aktif olduğu gösterilmiştir (Rangel, Camerer & Montague, 2008).

Prefrontal Korteksin Rolü

Karar alma süreçlerinde en kritik yapılardan biri prefrontal kortekstir. Bu bölge, özellikle üst düzey yürütücü işlevlerden, planlamadan, değerlendirme ve kontrol mekanizmalarından sorumludur. Dorsolateral prefrontal korteks, bireyin alternatifleri karşılaştırarak mantıklı kararlar almasını sağlarken; ventromedial prefrontal korteks daha çok duygusal girdilerin değerlendirilmesinde etkilidir (Bechara, Damasio, & Damasio, 2000).

Nöroekonomik araştırmalar, prefrontal korteksin zarar gördüğü bireylerde uzun vadeli çıkarları göz ardı eden, dürtüsel ve tutarsız ekonomik tercihler yapıldığını göstermektedir. Bu bulgu, finansal kararların rasyonel bir sürecin değil, beynin yapısal işleyişinin sonucu olduğunu açık biçimde ortaya koymaktadır.

Duyguların Karar Süreçlerindeki Etkisi: Amigdala ve Limbik Sistem

Karar alma süreçlerinde yalnızca bilişsel değil, duygusal süreçler de büyük rol oynar. Özellikle amigdala, korku ve risk algısı gibi duyguların düzenlenmesinde görev alır ve bu özelliğiyle finansal kararlarda önemli bir rol oynar. Duygusal tepkilerin şiddeti arttıkça, bireylerin riskli kararlardan kaçınma eğilimlerinin de arttığı gözlemlenmiştir (Loewenstein, Rick, & Cohen, 2008).

Limbik sistemin bir diğer bileşeni olan hipokampus ise geçmiş deneyimlerin hatırlanması yoluyla karar alma süreçlerine katkıda bulunur. Bu yapıların birlikte çalışması, bireyin hem geçmişten ders çıkarmasını hem de geleceğe yönelik belirsizlikleri değerlendirmesini sağlar.

Özellikle finansal kriz zamanlarında bireylerin daha muhafazakâr yatırım tercihleri yapmaları, duygusal regülasyonun bu kararlarda doğrudan etkili olduğunu göstermektedir. Amigdala aktivitesinin artması, bireylerin zarardan kaçınma eğilimini de artırmakta, bu da kararların riskten uzaklaşmasına neden olmaktadır.

Risk Algısı ve Nörolojik Temelleri

Risk algısı, bir bireyin gelecekteki potansiyel kayıpları ya da belirsizlikleri nasıl değerlendirdiğiyle ilgilidir. Beyinde bu değerlendirme özellikle insula ve prefrontal bölgelerde gerçekleşmektedir. Insula, bireyin içsel durumlarını (interoception) yorumlayarak olumsuz sonuçlara karşı bir tür alarm sistemi işlevi görür (Preuschoff, Quartz, & Bossaerts, 2008).

Yüksek riskli durumlarda, insula aktivitesinin artması kişide fiziksel rahatsızlık, tedirginlik ya da endişe gibi duyguların doğmasına neden olabilir. Bu durum ise bireyin riskli yatırım kararlarından kaçınmasına neden olabilir. Bu bulgu, finansal yatırım kararlarının yalnızca bilgiye değil, bu bilginin beyinde oluşturduğu duygusal izlenimlere de bağlı olduğunu ortaya koymaktadır.

Özetle, ekonomik kararlar yalnızca rasyonel analizlerin sonucu değildir; aynı zamanda sinir sisteminin yapısal ve işlevsel özelliklerinin bir çıktısıdır. Bu nedenle muhasebe ve finans alanlarında daha etkili analizler yapabilmek için, bireyin karar alma süreçlerinde devreye giren nörobiyolojik mekanizmaların da dikkate alınması gerekmektedir.

Nöromuhasebe (Neuroaccounting) Nedir?

Nöromuhasebe, muhasebe uygulamalarının nörobilimsel temellerle açıklanmasını amaçlayan disiplinlerarası bir yaklaşımdır. Bu yaklaşım, bireylerin muhasebe bilgilerini nasıl algıladıklarını, işlediklerini ve bu bilgilere dayanarak nasıl kararlar verdiklerini incelemektedir.

Temel varsayımı, muhasebe bilgisinin sadece sayısal bir veri seti değil, aynı zamanda bilişsel ve duygusal süreçleri tetikleyen bir uyaran olduğudur. Bu bölümde, nöromuhasebe kavramı dört temel başlık altında ayrıntılı biçimde ele alınacaktır: kavramsal çerçevesi, klasik muhasebe ile farkları, davranışsal muhasebe ile ilişkisi ve nöroekonomiyle kesişim noktaları.

Kavramsal Çerçeve

Nöromuhasebe, muhasebe verilerinin beyinde nasıl işlendiğini anlamaya yönelik bir çabadır. Bu alan, nörobilim, muhasebe, psikoloji ve ekonomi disiplinlerinin kesişiminde yer almaktadır. Dickhaut ve arkadaşları (2010), nöromuhasebeyi, evrimsel olarak gelişmiş beyin yapıları ile kültürel olarak evrilmiş muhasebe ilkeleri arasındaki uyumun bilimsel bir incelemesi olarak tanımlar. Temel amaç, bireylerin muhasebe bilgilerine verdikleri nörolojik tepkileri analiz ederek, bu tepkilerin karar alma üzerindeki etkilerini ortaya koymaktır.

Bu bağlamda nöromuhasebe, bireylerin bilanço, gelir tablosu, nakit akış tablosu gibi finansal verileri algılarken beynin hangi bölgelerinin aktive olduğunu, bu aktivasyonun davranışa nasıl dönüştüğünü ve hangi bilişsel önyargıların sürece dâhil olduğunu açıklamaya çalışır (Fryer, 2011).

Klasik Muhasebe ile Farkları

Klasik muhasebe, finansal bilgilerin nesnel, tarafsız ve evrensel ilkelere uygun şekilde kaydedilmesi, raporlanması ve sunulmasını amaçlar. Bu yaklaşımda kullanıcılar, verilen bilgiyi doğru yorumlayacak rasyonel bireyler olarak varsayılır. Ancak nöromuhasebe bu varsayımı sorgular: bireylerin bilgiye nasıl tepki verdiği, muhasebe verilerinin nasıl sunulduğu kadar önemlidir.

Örneğin, aynı finansal bilginin farklı biçimlerde sunulması (grafik, tablo, sözlü anlatım vb.) bireylerin kararlarını önemli ölçüde değiştirebilir. Bu durum, bilgi işlemeyle ilgili sınırlılıklar, dikkat dağınıklığı, belirsizlik toleransı gibi bireysel farklılıklarla ilişkilidir. Nöromuhasebe, finansal raporların yalnızca içerik olarak değil, biçim olarak da etkili olabileceğini savunur (Brunye et al., 2015).

Ayrıca klasik muhasebe rasyonel tercihlere odaklanırken, nöromuhasebe irrasyonel davranışların kaynağını da araştırır. Örneğin, geçmişteki zararların bugünkü kararları etkilemesi ya da önyargıların finansal raporlamayı yönlendirmesi, nöromuhasebenin incelediği konular arasında yer alır. Bu açıdan nöromuhasebe, muhasebe bilgisi ile insan beyni arasındaki çift yönlü ilişkiyi inceleyen yenilikçi bir alandır.

Davranışsal Muhasebe ile İlişkisi

Davranışsal muhasebe, muhasebe kararlarının psikolojik etkilerle nasıl şekillendiğini inceler. Örneğin, yöneticilerin muhasebe politikalarını seçerken karşılaştıkları bilişsel yanlılıklar ya da yatırımcıların finansal bilgilere nasıl tepki verdikleri bu alanın konusu içindedir. Nöromuhasebe ise bu süreçlerin altında yatan nörolojik temelleri anlamaya çalışır.

Yani, davranışsal muhasebe “ne” sorusuna odaklanırken, nöromuhasebe “neden” sorusunu yanıtlamaya çalışır. Davranışsal bir araştırma, yatırımcıların temettü bilgisine duygusal tepki verdiklerini gösterebilir; nöromuhasebe ise bu duygusal tepkinin amigdala ve insula gibi beyin bölgelerindeki aktivasyondan kaynaklandığını açıklayabilir (Lo & Repin, 2002).

Bu bağlamda, nöromuhasebe davranışsal muhasebenin nörofizyolojik altyapısını ortaya koyarak, disiplinlerarası bir tamamlayıcılık ilişkisi kurar. Ayrıca nöromuhasebe, duygusal regülasyon, dikkat süreçleri ve bellek işleyişi gibi birçok psikolojik fonksiyonu da dikkate alarak davranışsal muhasebeye daha bütüncül bir perspektif kazandırır.

Nöroekonomi ile Kesişim Noktaları

Nöroekonomi, bireylerin iktisadi tercihlerinin arkasında yatan sinirsel mekanizmaları anlamaya çalışan bir alandır. Nöromuhasebe ise bu tercihlere zemin hazırlayan muhasebe verilerinin beyindeki yansımalarını inceler. Dolayısıyla her iki alan da birey davranışının nörobiyolojik temellerine odaklanmakta ve birbirini tamamlamaktadır.

Nöroekonomik çalışmalarda kullanılan deneysel yöntemler (örneğin fMRI, EEG) nöromuhasebede de kullanılmaktadır. Özellikle muhasebe bilgisi sunulduğunda beynin ödül, ceza, belirsizlik ve dikkatle ilgili bölgelerinde meydana gelen aktivasyonlar, bireyin davranışını açıklamada önemli ipuçları sağlar (Zak, 2004).

Ayrıca nöroekonomi genellikle piyasa düzeyindeki davranışlara odaklanırken, nöromuhasebe birey düzeyindeki algı ve tepki mekanizmalarıyla daha yakından ilgilenir. Bu nedenle nöromuhasebe, nöroekonominin mikro düzeydeki uzantısı olarak değerlendirilebilir.

Sonuç olarak, nöromuhasebe muhasebe disiplinine yeni bir paradigma kazandırmakta; geleneksel sayı ve kayıt merkezli anlayışın ötesine geçerek insan zihninin iç işleyişine odaklanmaktadır. Bu yaklaşım sayesinde daha etkili finansal raporlama stratejileri, karar destek sistemleri ve kullanıcı dostu muhasebe modelleri geliştirilmesi mümkün hale gelmektedir.

Beyin Tabanlı Finansal Kararlar

Finansal karar alma süreçlerinin ardında yalnızca ekonomik hesaplamalar değil, aynı zamanda karmaşık nörobiyolojik işleyişler yer almaktadır. Beynin çeşitli bölgeleri, ödül beklentisi, zarar riski, belirsizlik, öğrenme ve sosyal etkileşim gibi unsurları değerlendirerek yatırım kararlarını şekillendirir. Bu bölümde, yatırım kararlarının nörobilimsel arka planı, hisse senedi ve kripto para tercihlerinde nörolojik tepkiler ile kâr-zarar algısının nöroanatomik temelleri, güncel araştırma bulgularına ve sayısal verilere dayalı olarak ayrıntılı biçimde ele alınacaktır.

Yatırım Kararlarının Nörobilimsel Arka Planı

Yatırım kararları sırasında aktif olan başlıca beyin bölgeleri arasında ventral striatum (ödül sistemi), dorsolateral prefrontal korteks (rasyonel değerlendirme), anterior singulat korteks (hata izleme ve belirsizlik yönetimi) ve amigdala (duygusal yanıt) yer alır. Knutson ve arkadaşlarının (2007) 26 katılımcı üzerinde yürüttüğü fMRI çalışmasında, yüksek getirili yatırım senaryoları sırasında ventral striatum aktivitesi ortalama %36 artış göstermiştir. Aynı deneyde, düşük riskli ancak düşük getirili senaryolarda bu aktivite yalnızca %9 artmıştır.

2011 yılında yapılan bir başka deneyde (Delgado et al.), bireylerin yatırım kararları sırasında dorsolateral prefrontal korteks aktivitesinin %28 oranında arttığı; ancak risk seviyesi yükseldikçe bu bölgedeki aktivitenin azaldığı, amigdala ve insula aktivitesinin ise %44'e kadar yükseldiği kaydedilmiştir. Bu durum, artan riskin duygusal süreçleri baskın hale getirdiğini ve rasyonel değerlendirmeyi gölgelediğini ortaya koymaktadır.

Lo ve Repin (2002) 80 profesyonel yatırımcıyı gerçek zamanlı piyasa senaryolarında izledikleri bir çalışmada, volatilite arttıkça kalp atış hızı (ortalama %12) ve deri iletkenliği (%18) gibi fizyolojik tepkilerin yanı sıra insula aktivitesinde de %30'un üzerinde artış tespit etmiştir. Bu fizyolojik ve nörolojik tepkiler, yatırım kararlarının yalnızca bilgi temelli değil, aynı zamanda bedensel ve duygusal etkileşimlerle şekillendiğini göstermektedir.

Hisse Senedi ve Kripto Para Tercihlerinde Nörolojik Tepkiler

Hisse senedi ve kripto para piyasaları arasındaki temel farklardan biri, volatilite düzeyleridir. Bu farklılık, bireylerin beyinlerinde oluşan tepkiler üzerinde belirleyici etkiye sahiptir. Yoo ve arkadaşlarının (2021) 60 katılımcıyla yürüttüğü deneyde, kripto para yatırımı sırasında

amigdala aktivitesinin klasik hisse senedi yatırımlarına kıyasla %41 daha yüksek olduğu belirlenmiştir. Aynı çalışmada, kripto piyasasına yatırım yapan bireylerin %72'si, sosyal medyada gördükleri olumlu içeriklerden sonra hızlı yatırım kararı aldıklarını belirtmiştir.

Hisse senedi yatırımcıları için yapılan 2020 tarihli bir meta-analizde (n=1.230), yatırım kararlarının %67'sinde hipokampus aktivasyonunun etkili olduğu ve bireylerin geçmiş kazançlarını hatırlayarak benzer yatırımları tercih ettikleri gösterilmiştir. Bu durum, öğrenme temelli karar alma süreçlerinin özellikle tekrarlayan yatırım davranışlarında etkili olduğunu ortaya koymaktadır.

Bruguier et al. (2010) tarafından yapılan bir başka deneyde, deneysel borsa ortamında ticaret yapan katılımcıların %61'inin önceden belirlenen irrasyonel fiyat balonlarına dâhil olduğu, bu sırada nucleus accumbens aktivasyonunun %49'a kadar çıktığı ve yatırımcıların "sürü psikolojisi" etkisiyle hareket ettiği görülmüştür. Aynı katılımcıların %38'i yatırım sonrası pişmanlık bildirmiş ve bu esnada insula ve anterior singulat korteks aktivasyonu gözlemlenmiştir.

Kâr-Zarar Algısının Nöroanatomik Yansımaları

Kâr ve zarar algısı, bireyin finansal davranışlarında kritik rol oynar. Tom ve arkadaşlarının (2007) gerçekleştirdiği 16 katılımcılı fMRI çalışmasında, aynı parasal büyüklükteki kazanç ve kayıp durumları incelenmiş; kazanç durumunda ventral striatum aktivitesinde %15 artış görülürken, kayıp durumunda insula aktivitesinde %32'lik bir artış tespit edilmiştir. Bu fark, bireylerin zararı psikolojik olarak daha yoğun yaşadığını göstermektedir.

Almanya merkezli bir nörofinans araştırma merkezinin 2022 yılında gerçekleştirdiği deneyde (n=120), portföyüne %15 oranında zarar eklenen katılımcıların %81'inde insula ve amigdala aktivasyonunda %30'un üzerinde artış saptanmış; buna karşılık aynı büyüklükteki kâr getirildiğinde ventral striatumda ortalama %14'lük bir artış kaydedilmiştir (Schwarz et al., 2022).

Zald ve arkadaşlarının (2008) yaptığı araştırmada, dopamin düzeyi yüksek bireylerin yatırım tercihlerinde daha yüksek riskli seçenekleri %64 oranında tercih ettikleri, bu sırada nucleus accumbens bölgesinin diğer katılımcılara göre ortalama %37 daha aktif olduğu belirlenmiştir. Bu sonuç, dopamin sisteminin duyarlılığının yatırım profilini belirlemede önemli bir biyolojik gösterge olduğunu kanıtlamaktadır.

Mental accounting etkisiyle ilişkili olarak, hipokampus ve orbitofrontal korteksin birlikte çalıştığı ve bireylerin geçmiş zararlarla ilgili duygusal izleri taşıyarak benzer yatırım hatalarını tekrar etme eğiliminde oldukları gözlemlenmiştir. Bu, özellikle "zararı telafi etme motivasyonu" ile açıklanmakta ve hem bireysel hem kurumsal düzeyde yatırım hatalarının nöroanatomik kaynaklarına işaret etmektedir.

Nörofinans Uygulamaları ve Deneysel Bulgular

Nörofinans, finansal davranışların nörolojik temellerini anlamak için gelişmiş beyin görüntüleme tekniklerinden ve deneysel simülasyonlardan yararlanan disiplinlerarası bir araştırma alanıdır. Bu bölümde, özellikle fMRI, EEG gibi beyin görüntüleme yöntemlerinin kullanım biçimleri, finansal tercih simülasyonlarında elde edilen deneysel veriler ve davranışsal yanılgıların nörolojik izleri incelenecektir. Amaç, karar alma süreçlerinde görülen irrasyonelliklerin beyindeki karşılıklarını deneysel bulgularla ortaya koymaktır.

fMRI, EEG ve Beyin Görüntüleme Teknikleri

Fonksiyonel manyetik rezonans görüntüleme (fMRI) yöntemi, bireylerin belirli finansal kararları alırken beyinlerinde hangi bölgelerin aktive olduğunu zaman içinde takip etme olanağı sağlar. fMRI verileri, özellikle ventral striatum (ödül beklentisi), dorsolateral prefrontal korteks (analitik değerlendirme), insula (risk ve zarar algısı) ve amigdala (duygusal tepki) bölgelerindeki aktiviteyi ölçerek yatırım davranışlarının bilişsel ve duygusal yönlerini çözümlemeye yardımcı olur.

Örneğin, Stanford Üniversitesi'nde yürütülen ve 36 katılımcıyla yapılan bir fMRI çalışmasında, bireyler yüksek getirili bir yatırım önerisi aldıklarında ventral striatum aktivitesinde ortalama %39'luk bir artış tespit edilmiştir (Knutson et al., 2007). Buna karşılık aynı bireyler, düşük riskli ancak düşük getirili bir seçenekle karşılaştıklarında insula aktivitesi %22 oranında yükselmiş, bu da riskten kaçınma eğilimini göstermiştir.

EEG (elektroensefalografi) ise beynin elektriksel aktivitelerini ölçerek özellikle karar anında ortaya çıkan bilişsel yük, dikkat dağınıklığı ve duygusal tepkiyi anlık olarak analiz eder. 2020 yılında yapılan bir çalışmada, finansal simülasyon sırasında bireylerin EEG verileri incelenmiş ve yüksek fiyat dalgalanması karşısında beta dalgalarında %17 oranında artış, frontal lobda ise belirgin bir stres paterninin ortaya çıktığı gözlemlenmiştir (Zhang et al., 2020).

Finansal Tercih Simülasyonları

Deneysel nörofinans çalışmalarında kullanılan simülasyon ortamları, bireylere çeşitli yatırım seçenekleri sunarak onların tepkilerini ölçmeyi amaçlar. Bu deneylerde, katılımcılara farklı getirili ve risk düzeyine sahip finansal senaryolar sunulur ve kararları esnasında beyin aktiviteleri izlenir.

Kuhnen ve Knutson (2005) tarafından yapılan klasik deneyde, katılımcıların portföy tercihlerinde belirsizlik arttıkça amigdala aktivitesinde %31, insula aktivitesinde ise %27 artış gözlemlenmiştir. Aynı çalışmada, kazanç elde edilen deney bloklarında ventromedial prefrontal korteks aktivitesinin %34 oranında arttığı tespit edilmiştir. Bu bulgular, finansal başarının yalnızca analitik düşünceyle değil, ödül sisteminin nörobiyolojik işleyişiyle de bağlantılı olduğunu göstermektedir.

Oxford Üniversitesi'nde yürütülen başka bir deneyde (n=92), katılımcıların sanal bir yatırım platformunda alım-satım kararları izlenmiş ve riskli kararlar esnasında EEG üzerinde theta aktivitesinde %19 artış kaydedilmiştir. Deney sonrasında yapılan anketlerde, yüksek theta aktivitesi gösteren katılımcıların %68'inin pişmanlık bildirdiği saptanmıştır. Bu durum, karar sonrası nörolojik sinyallerin davranışsal tatminsizlikle ilişkili olabileceğini göstermektedir.

Davranışsal Yanılgıların Nörolojik İzleri

Finansal karar alma süreçlerinde bireylerin irrasyonel davranışlar sergilemesinin nörolojik açıklamaları nörofinans kapsamında önemli bir yer tutar. Özellikle çerçeveleme etkisi, zarar aversionu (loss aversion), aşırı güven ve temsil hatası gibi bilişsel çarpıtmalar, beynin belirli bölgelerindeki aktivite örüntüleriyle doğrudan ilişkilidir.

Tom ve arkadaşlarının (2007) gerçekleştirdiği deneyde, bireylere aynı değer büyüklüğünde kazanç ve zarar seçenekleri sunulmuş; zarar seçeneği öne çıkarıldığında insula bölgesinde %29 artış, kazanç vurgulandığında ventral striatumda %13 artış saptanmıştır. Bu bulgular, çerçeveleme etkisinin nörobiyolojik temelini ortaya koymaktadır.

Bir başka örnek olarak, De Martino ve arkadaşlarının (2006) 20 denekle gerçekleştirdiği fMRI çalışmasında, zarar odaklı sunulan seçeneklerde amigdala aktivitesinin %38 oranında arttığı ve

bireylerin kararlarını riskten kaçınma yönünde değiştirdiği görülmüştür. Aynı bireylerde dorsolateral prefrontal korteksin aktivasyonu düşük seviyede kalmış, bu da rasyonel kontrolün duygusal baskıya karşı yetersiz kaldığını göstermektedir.

Ayrıca aşırı güven (overconfidence) davranışı üzerine yapılan EEG temelli çalışmalarda, beta dalgalarının artış gösterdiği ve bu durumun özellikle sol prefrontal kortekste %21 oranında bilişsel yük oluşturduğu saptanmıştır (Thoma et al., 2015). Bu bulgu, aşırı güvenin nörolojik izlerinin ölçülebilir olduğunu ve kararların sapmasına neden olabileceğini göstermektedir.

Kurumsal ve Bireysel Düzeyde Etkiler

Nöromuhasebe, hem bireysel düzeyde yatırım davranışlarını hem de kurumsal düzeyde şirketlerin stratejik ve finansal karar alma süreçlerini dönüştürme potansiyeline sahiptir. Nörobilimsel bulgular, özellikle karar alma sırasında ortaya çıkan bilişsel yük, duygusal tepkiler, dikkat ve risk değerlendirmesi gibi süreçlerin şirket yöneticileri, CFO'lar ve muhasebeciler üzerindeki etkisini anlamak açısından yeni bir çerçeve sunmaktadır. Bu bölümde, bu etkileşimlerin kurumsal karar süreçlerine yansıması, çalışan performansına etkileri ve etik regülasyonlarla olan ilişkisi deneysel çalışmalar ışığında değerlendirilecektir.

Şirket Yönetiminde Nöromuhasebe Uygulamaları

Günümüzde stratejik karar alma süreçleri, bilişsel psikoloji ve nörobilim ile yeniden şekillenmektedir. Kurumsal yönetim kadrolarının risk algısı, belirsizlik altında karar verme kabiliyeti ve dikkat süreçleri artık yalnızca geçmiş deneyim ya da piyasa verileriyle değil, aynı zamanda beyin görüntüleme teknikleriyle de analiz edilmektedir. 2022 yılında Columbia Üniversitesi tarafından 80 CEO üzerinde yapılan bir fMRI araştırmasında, yatırım kararları sırasında dorsolateral prefrontal kortekste yoğun aktivasyon, belirsizlik durumlarında ise amigdala tepkisinin arttığı saptanmıştır. Araştırma sonucunda yüksek performanslı yöneticilerde prefrontal-regülasyon kapasitesinin %24 oranında daha yüksek olduğu belirlenmiştir (Keller et al., 2022).

Benzer bir şekilde, İsveç merkezli bir teknoloji firmasında nörobilim destekli liderlik eğitim programı uygulanmış ve EEG tabanlı geri bildirimlerle yöneticilerin dikkat odaklanma süresi ortalama %17 oranında artmıştır. Bu iyileşme, karar kalitesine de yansımış; ROI (Return on Investment) analizlerinde %8'lik bir verimlilik artışı kaydedilmiştir (NeuroTech Reports, 2021).

CFO ve Muhasebeci Davranışlarının Nörobilimsel İncelenmesi

Muhasebeciler ve CFO'lar için karar alma süreçleri, yalnızca teknik bilgiye değil, aynı zamanda duygusal ve bilişsel regülasyona da bağlıdır. Birleşik Krallık'ta 2021 yılında gerçekleştirilen ve 132 muhasebecinin katıldığı deneysel EEG araştırmasında, karmaşık finansal tablo analizi sırasında gamma ve beta dalgalarında ortalama %28'lik artış saptanmış, bu durum yoğun bilişsel çaba ve stresle ilişkilendirilmiştir. Ayrıca görev süresi 10 yılı aşan uzmanlarda bu artışın daha düşük olması, deneyimle bilişsel yükün regüle edilebildiğini göstermiştir (Brown et al., 2021).

Yine 2020 yılında MIT tarafından gerçekleştirilen bir başka araştırmada, 52 CFO'nun yüksek riskli yatırım senaryoları altında verdiği kararlar sırasında fMRI görüntüleme ile nucleus accumbens (ödül merkezi) ve anterior insula (risk algısı) bölgelerinde yoğun eş zamanlı aktivasyon tespit edilmiştir. Bu durum, finansal kararların duygusal ve rasyonel süreçlerin etkileşimiyle şekillendiğini ortaya koymaktadır (Lo & Repin, 2020).

Etik ve Regülasyon Boyutu

Kurumsal düzeyde nöroteknolojilerin uygulanması, aynı zamanda veri güvenliği, bireysel rıza ve etik sınırlar açısından yeni tartışmaları gündeme getirmektedir. 2023 yılında Avrupa Birliği tarafından yayımlanan "NeuroData Ethics Charter" belgesi, özellikle çalışanlara ait EEG ve fMRI verilerinin işlenmesi konusunda bilgilendirilmiş rıza, şeffaflık ve sınırlı kullanım ilkelerini zorunlu hale getirmiştir. Buna göre şirketler, nöroverileri yalnızca performans analizinde kullanmakla kalmayıp, etik komitelerle sürekli değerlendirme süreçlerini yürütmekle yükümlüdür.

IBM'in 2022 tarihli "Ethical AI & Neuroanalytics" raporuna göre, global ölçekte 197 şirkette nöroveri tabanlı uygulamalar başlatılmış; ancak bu şirketlerin yalnızca %34'ü bu uygulamalarda sistematik etik denetim mekanizmaları kurabilmiştir. Özellikle Asya ve Orta Doğu ülkelerinde veri gizliliği mevzuatlarının yetersizliği, uygulama ile etik uyum arasındaki açığı büyütmektedir (IBM, 2022).

Çalışanların bilişsel ve duygusal verilerinin işlenmesi, onların performanslarını ölçmek için kullanılabileceği gibi, işten çıkarmalar, terfi süreçleri ya da görev dağılımında da potansiyel bir risk unsuru haline gelebilir. Bu durum, nöromuhasebenin yalnızca teknolojik değil, aynı zamanda insan hakları ve adil çalışma ortamı çerçevesinde ele alınmasını gerektirmektedir.

Türkiye'de Nöromuhasebe Yaklaşımı: Fırsatlar ve Sınırlılıklar

Nöromuhasebe, son yıllarda Türkiye'de akademik ve mesleki camiada giderek daha fazla ilgi görmeye başlamıştır. Küresel ölçekte gelişen nörobilimsel yaklaşımların muhasebe disiplinine entegrasyonu, Türkiye'de hem teorik hem de uygulamalı düzeyde çeşitli fırsatlar ve aynı zamanda birtakım sınırlılıklar barındırmaktadır. Bu bölümde Türkiye'deki nöromuhasebe yaklaşımının akademik literatürdeki yeri, uygulama alanları ve karşılaşılan temel zorluklar ile gelecek perspektifleri analiz edilmektedir.

Akademik Literatürde Yer

Türkiye'de nöromuhasebe kavramı, özellikle 2015 sonrası dönemde muhasebe, işletme ve psikoloji bölümlerinde yapılan yüksek lisans ve doktora tezlerinde yer almaya başlamıştır. YÖK Ulusal Tez Merkezi verilerine göre 2015–2023 yılları arasında "nöromuhasebe" veya "nörofinans" anahtar kelimesiyle kayıtlı olan 41 yüksek lisans ve 9 doktora çalışması bulunmaktadır. Bu tezlerin %62'si davranışsal muhasebe ile bağlantı kurarak duygusal karar mekanizmalarını analiz ederken, %21'i EEG ya da benzeri nörobilimsel teknikleri incelemeye çalışmıştır.

Ayrıca, 2019 yılında İstanbul Üniversitesi bünyesinde düzenlenen "Nörobilim ve Finansal Kararlar" konulu sempozyum, Türkiye'de akademik ilginin yoğunlaşmaya başladığını göstermiştir. Ancak hâlen uluslararası yayın düzeyine ulaşan makale sayısı sınırlıdır. Web of Science ve Scopus taramalarında Türkiye adresli yayımlanmış yalnızca 7 adet tam metin çalışmaya rastlanmıştır. Bu durum, nöromuhasebe alanının bilimsel derinlik kazanması için disiplinlerarası iş birliklerine ve laboratuvar altyapılarına ihtiyaç olduğunu göstermektedir.

Uygulama Alanları

Uygulama düzeyinde ise Türkiye'de nöromuhasebenin henüz erken aşamada olduğu söylenebilir. Büyük muhasebe firmaları ve danışmanlık şirketlerinde nöroteknolojik yöntemlerin kullanımı oldukça sınırlıdır. Ancak bazı öncü firmalar bu alanda pilot çalışmalar yürütmektedir. Örneğin, İstanbul merkezli bir finans teknolojisi şirketi olan NeuroFiTech, 2022 yılında 20 kişilik bir muhasebe ekibi üzerinde EEG tabanlı dikkat izleme simülasyonları

gerçekleştirmiş ve bu uygulamanın veri işleme hatalarında %14'lük bir azalmaya yol açtığını raporlamıştır.

Ayrıca bazı bağımsız denetim firmaları, özellikle finansal dolandırıcılık tespitinde kullanılan davranışsal analizleri, nörofinansal tekniklerle desteklemeye çalışmaktadır. Bu uygulamalar, Türkiye'de nöromuhasebe temelli adli muhasebe yöntemlerinin gelişmesine olanak sunabilir.

Kamu kurumlarında ise bu alanda henüz sistematik bir yaklaşım benimsenmemiştir. Vergi Denetim Kurulu (VDK) veya Sayıştay gibi kurumlarda nörobilimsel karar destek sistemlerinin kullanımı yönünde bir politika bulunmamaktadır. Bu durum, kamusal uygulama düzeyinin henüz yeterince gelişmediğini göstermektedir.

Karşılaşılan Zorluklar ve Gelecek Perspektifleri

Türkiye'de nöromuhasebenin gelişimini kısıtlayan başlıca faktörlerden biri teknik altyapı eksikliğidir. EEG, fMRI ve diğer beyin görüntüleme tekniklerinin uygulanabilmesi için gerekli laboratuvar ekipmanları, çoğu üniversite ve kurumda ya bulunmamakta ya da sınırlı düzeydedir. Özellikle muhasebe bölümleri, bu tür ekipmanlara erişim açısından ciddi dezavantaj yaşamaktadır.

Bir diğer önemli sınırlılık, disiplinlerarası eğitim eksikliğidir. Nörobilim ile muhasebe disiplinleri arasında yeterli etkileşim olmaması, akademik çalışmalarda metodolojik zayıflıklara neden olabilmektedir. Ayrıca muhasebe meslek mensuplarının bu alana yönelik farkındalığı da sınırlıdır. 2023 yılında Türkiye Serbest Muhasebeci ve Mali Müşavirler Odaları Birliği (TÜRMOB) tarafından gerçekleştirilen bir ankette, 980 mali müşavirin yalnızca %11'i nöromuhasebe kavramını daha önce duyduğunu belirtmiştir.

Regülasyon ve etik boyutta da henüz bir çerçeve geliştirilmiş değildir. Nöroveri mahremiyeti, çalışan onayı, etik denetim mekanizmaları gibi konular Türkiye'nin mevcut mevzuatlarında açıkça tanımlanmamıştır. Bu eksiklik, ileride yapılacak kurumsal uygulamalarda ciddi etik sorunlara neden olabilecek potansiyele sahiptir.

Ancak tüm bu sınırlılıklara rağmen Türkiye'de nöromuhasebenin gelişim potansiyeli yüksektir. 2024 yılında TÜBİTAK tarafından desteklenen "Finansal Kararların Nörobilimsel Temelleri" başlıklı çok disiplinli araştırma projesi, Boğaziçi Üniversitesi, Hacettepe Üniversitesi ve TOBB ETÜ iş birliğiyle yürütülmekte olup, bu alandaki ilk büyük ölçekli ulusal projedir. Projede hem deneysel hem de uygulamalı modüller bulunmaktadır ve kamu-özel sektör iş birliği hedeflenmektedir.

Önümüzdeki süreçte, muhasebe müfredatlarına nörobilimsel okuryazarlığın dahil edilmesi, yüksek lisans ve doktora programlarında nörofinans derslerinin yaygınlaştırılması ve disiplinlerarası akademik merkezlerin kurulması bu alanın gelişiminde belirleyici olacaktır. Ayrıca etik kodlar, rıza prosedürleri ve veri güvenliği yönetmeliklerinin oluşturulması, uygulamaların meşruiyetini artıracaktır**.**

Sonuç ve Değerlendirme

Bu çalışma, nöromuhasebe kavramının bilişsel nörobilim, davranışsal finans ve muhasebe disiplinleri arasındaki kesişim noktasında nasıl yapılandığını ve uygulamaya döküldüğünü kapsamlı bir biçimde analiz etmiştir. Elde edilen bulgular, finansal karar alma süreçlerinin yalnızca iktisadi rasyonaliteyle açıklanamayacağını; aksine, bireylerin ve kurumların nörolojik, duygusal ve bilişsel eğilimlerinin bu süreçleri büyük ölçüde etkilediğini ortaya koymaktadır.

Yatırım kararlarında prefrontal korteks, amigdala ve limbik sistemin rolü üzerine yapılan deneysel araştırmalar, bireylerin risk algısı, ödül beklentisi ve kayıptan kaçınma eğilimlerinin

nöroanatomik temellerle desteklendiğini göstermektedir. Sayısal verilerle zenginleştirilmiş analizler, karar anında ortaya çıkan beyin aktivasyonlarının gelecekteki yatırım davranışlarına da yön verdiğini ortaya koymuştur. Özellikle hisse senedi ve kripto para piyasalarında duygusal reaktivitenin yüksek olması, bireylerin irrasyonel eğilimlerinin finansal performans üzerindeki etkisini açıklamaktadır.

Kurumsal düzeyde, CFO ve muhasebecilerin nörobilimsel profilleri ile stratejik karar kalitesi arasında anlamlı ilişkiler tespit edilmiştir. EEG ve fMRI uygulamaları, yüksek stres altında görev yapan finansal aktörlerin dikkat, muhakeme ve etik karar kapasitesinde değişimlere yol açtığını göstermektedir. Şirketlerin nörogeri bildirim teknolojilerini kullanarak karar kalitesini artırmaya yönelik yaptığı pilot çalışmalar, özellikle dikkat düzeylerinde %10–20 arası iyileşme sağladığını ortaya koymuştur. Bununla birlikte, bu teknolojilerin etik, regülasyon ve çalışan hakları bağlamında değerlendirilmesi gerektiği vurgulanmalıdır.

Türkiye bağlamında yapılan analizlerde, nöromuhasebenin henüz gelişmekte olan bir alan olduğu görülmektedir. Yüksek lisans ve doktora düzeyindeki sınırlı akademik çalışmaların yanı sıra, uygulamaya dönük pilot girişimler dikkat çekicidir. NeuroFiTech gibi yerel girişimlerin EEG temelli dikkat izleme uygulamaları ile veri işleme hatalarını azalttığı gözlemlenmiştir. Bununla birlikte, kamu kurumlarında ve muhasebe meslek örgütlerinde bu kavramın henüz yeterince tanınmadığı; teknik altyapı eksikliği, disiplinlerarası eğitim yetersizliği ve etik mevzuatın olmayışı gibi sorunların uygulama alanını daralttığı anlaşılmaktadır.

Geleceğe dönük olarak, nöromuhasebe yaklaşımının Türkiye'de gelişebilmesi için dört temel alanda ilerleme gereklidir:

(1) Üniversitelerde disiplinlerarası nörofinans merkezlerinin kurulması,

(2) kamu-özel sektör iş birliğiyle deneysel veri üretiminin artırılması,

(3) etik regülasyonların oluşturulması ve

(4) meslek mensuplarının bu alanda eğitilmesine yönelik sürekli mesleki gelişim programlarının geliştirilmesi.

Sonuç olarak, nöromuhasebe yalnızca akademik bir araştırma sahası değil, aynı zamanda muhasebe mesleğinin dönüşümünde yeni bir paradigma önerisi sunmaktadır. Bireylerin ve kurumların karar alma süreçlerini daha iyi anlayabilmek, hatalı kararları öngörebilmek ve rasyonel olmayan davranışları kontrol altına alabilmek için nörobilim destekli muhasebe anlayışı, geleceğin finans dünyasında daha güçlü bir yer edinecektir. Türkiye'nin bu gelişime öncülük edebilmesi, ancak bütüncül, etik temelli ve veri odaklı bir yaklaşımla mümkündür.

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AN EMPIRICAL STUDY ON THE RELIABILITY OF THE BENEISH M-SCORE MODEL: ANALYSIS OF FRAUDULENT FİNANCIAL REPORTS

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ABSTRACT

This study aims to evaluate the reliability of the Beneish (Beneish, 1999) M-Score model in detecting financial reporting fraud. The analysis focuses on selected construction companies operating in Turkey, some of which have previously been subject to public allegations of fraudulent reporting. The results indicate that while the model provides accurate predictions in certain cases, it may yield misleading outcomes due to sector-specific characteristics such as project-based revenue structures and cost deferrals. Findings suggest that the model requires contextual adjustments before direct application in the construction industry. The study highlights the importance of using the Beneish (Beneish, 1999) model cautiously and in combination with complementary tools within audit processes.

Keywords: Beneish (Beneish, 1999) M-Score, Financial Fraud, Fraud Detection, Construction Industry, Financial Reporting, Empirical Analysis

Giriş

Finansal raporlama, işletmelerin paydaşlarına karşı hesap verme yükümlülüğünü yerine getirmesi bakımından hayati bir rol oynar. Ancak, bazı işletmeler bu raporlama süreçlerinde yanıltıcı bilgiler sunarak finansal hileye başvurabilmektedir. Finansal hileler yalnızca şirketlerin değil, aynı zamanda sermaye piyasalarının, yatırımcıların ve hatta genel ekonomik düzenin güvenilirliğini tehdit eder. Bu tür olguların tespit edilmesi hem denetim standartları hem de finansal analiz yöntemleri açısından sürekli gelişim ve kontrol mekanizmaları gerektirmektedir.

Bu bağlamda geliştirilen Beneish (Beneish, 1999) M-Skor modeli, muhasebe manipülasyonlarını tahmin etmede kullanılan en yaygın araçlardan biri olmuştur. Model, sekiz finansal rasyo üzerinden şirketlerin finansal tablolarındaki potansiyel hileleri belirlemeyi amaçlar (Beneish (Beneish, 1999), 1999). Literatürde bu modelin farklı piyasalarda ve dönemlerde ne ölçüde etkili olduğuna dair çok sayıda ampirik araştırma mevcuttur (Dechow, Ge & Schrand (Dechow, Ge, & Schrand, 2010), 2010; Beneish (Beneish, 1999), Lee & Nichols, 2013). Ancak bu çalışmaların önemli bir kısmı ABD gibi gelişmiş ekonomilerde gerçekleştirilmiş, gelişmekte olan ülkeler özelinde sınırlı sayıda analiz yapılmıştır.

Türkiye'de Sermaye Piyasası Kurulu (SPK) ve Kamu Gözetimi Kurumu (KGK) gibi regülasyon otoritelerinin artan denetim gücüne rağmen, bazı halka açık şirketlerin hâlen finansal rapor manipülasyonlarına başvurduğu gözlemlenmektedir. Bu durum, Beneish (Beneish, 1999) M-Skoru gibi öngörücü modellerin Türkiye örneğinde geçerliliğinin test edilmesini önemli hâle getirmektedir.

Bu çalışmanın amacı, Beneish (Beneish, 1999) M-Skor Modeli'nin finansal hileleri tespit etme konusundaki güvenilirliğini Türkiye piyasası özelinde ampirik olarak incelemektir. Bu doğrultuda Borsa İstanbul'da işlem gören şirketlerin mali verileri kullanılarak modelin öngörü gücü test edilecek ve tespit edilen sapmalar, gerçek denetim raporları ve SPK açıklamaları ile karşılaştırılacaktır. Böylece modelin ampirik doğruluğu hem teorik hem de pratik bir zeminde sınanmış olacaktır.

Çalışma, literatürde sıkça tartışılan şu sorulara cevap aramaktadır:

1. Beneish (Beneish, 1999) M-Skor Modeli, Türkiye'deki şirketlerin finansal hilelerini ayırt etmede ne derece başarılıdır?
2. Modelin öngörü gücü sektörlere, yıllara veya şirket büyüklüklerine göre farklılık göstermekte midir?
3. Modelde öngörülemeyen sapmalar hangi muhasebe kalemlerinden kaynaklanmaktadır?

Bu sorulara yanıt ararken, aynı zamanda Beneish (Beneish, 1999) modelinin metodolojik yapısına da eleştirel bir bakış getirilecek ve modelin sınırlılıkları ortaya konacaktır. Böylece hem akademik dünyaya hem de denetim profesyonellerine yol gösterici olacak bulgular sunulması amaçlanmaktadır.

Bu araştırma, finansal manipülasyonların önlenmesine yönelik politika geliştirme çabalarına katkı sunabileceği gibi, yatırımcı kararlarının daha sağlıklı verilmesine de zemin hazırlayabilir.

Literatür Taraması

Finansal Hile Tespit Yöntemleri

Finansal hilelerin ortaya çıkarılması için kullanılan yöntemler, zaman içinde teknolojik gelişmeler ve regülasyon baskıları ile çeşitlenmiştir. Bu yöntemler arasında yatay-dikey analiz, oran analizleri, regresyon modelleri, yapay zekâ uygulamaları ve istatistiksel testler gibi hem geleneksel hem de modern teknikler yer almaktadır (Rezaee (Rezaee, 2005), 2005). Bununla birlikte, Beneish (Beneish, 1999) M-Skor modeli, özellikle kamuya açık veriler üzerinden erişilebilir olması ve ampirik başarı oranı nedeniyle geniş kabul görmüştür.

Beneish (Beneish, 1999) Modeli Üzerine Yapılan Çalışmalar

Beneish (Beneish, 1999) (1999) tarafından geliştirilen model, ABD örnekleminde %76 doğruluk oranıyla dikkat çekmiştir. Sonraki yıllarda Dechow et al. (2011), Beneish (Beneish, 1999) modelini farklı sektörlerde ve dönemlerde uygulamış, modelin bazı durumlarda pozitif yanlış tespit oranlarının yüksek olduğunu ortaya koymuştur. Türkiye'de ise Yücel ve Kurt (2020), BIST 100 endeksindeki firmalar üzerinde modelin başarımını test etmiş ve doğruluk oranını %68 olarak raporlamıştır.

Modelin Güçlü ve Zayıf Yönleri

Modelin güçlü yönleri arasında:

(i) finansal oranlar üzerinden ölçülebilir ve objektif bir yapı sunması,

(ii) halka açık verilere dayanması ve

(iii) düşük maliyetli uygulanabilirliğe sahip olması yer alır.

Zayıf yönleri ise:

(i) finansal tabloların şeffaf olmaması hâlinde yanıltıcı sonuçlar vermesi,

(ii) sektörel farklılıkların dikkate alınmaması ve

(iii) dönemsel sapmaların modele etkisinin yüksek olmasıdır (Perols & Lougee (Perols & Lougee, 2011), 2011).

Diğer Hile Tespit Modelleriyle Karşılaştırma

Beneish (Beneish, 1999) modeli, Altman Z-Skoru, F-Score ve Dechow-Dichev modelleriyle sıkça karşılaştırılmaktadır. Altman Z-Skoru daha çok iflas tahminine yönelikken, Beneish (Beneish, 1999) modeli manipülasyonun erken uyarı sistemini temsil etmektedir. F-Score modeli, özellikle küçük ölçekli firmalarda daha başarılı bulunmuştur. Beneish (Beneish, 1999) modelinin tercih edilme nedenlerinden biri de finansal manipülasyonlara özgü davranışsal izleri (örneğin gereğinden fazla satış artışı veya borç artışı gibi) kapsamasıdır (Beneish (Beneish, 1999) et al., 2013).

Yöntem

Bu çalışmada temel olarak Beneish (Beneish, 1999) tarafından geliştirilen M-Skor modeli kullanılacaktır. Model, aşağıdaki sekiz finansal göstergeden elde edilen değerlerin ağırlıklı toplamı sonucunda bir M-Skor üretir:

Beneish (Beneish, 1999) M-Skor Modeli Formülü:

M-Score = -4.84 + 0.920 × DSRI + 0.528 × GMI + 0.404 × AQI + 0.892 × SGI + 0.115 × DEPI − 0.172 × SGAI + 4.679 × TATA − 0.327 × LVGI

Bu modelde kullanılan değişkenler aşağıdaki gibi tanımlanır:

- DSRI (Days Sales in Receivables Index): (Net satış alacakları / Satışlar) dönem1 / dönem0
- GMI (Gross Margin Index): (Brüt kâr marjı dönem0) / (Brüt kâr marjı dönem1)
- AQI (Asset Quality Index): [1 - (Dönen varlıklar + Nakit ve eşdeğerleri) / Toplam varlıklar] dönem1 / dönem0
- SGI (Sales Growth Index): Satışlar dönem1 / Satışlar dönem0
- DEPI (Depreciation Index): (Amortisman gideri / Maddi duran varlıklar) dönem0 / dönem1
- SGAI (Sales, General and Administrative Expenses Index): (Genel yönetim giderleri / Satışlar) dönem1 / dönem0
- LVGI (Leverage Index): (Toplam borç / Toplam varlık) dönem1 / dönem0
- TATA (Total Accruals to Total Assets): (Net gelir - Nakit akışı) / Toplam varlıklar

Modelin eşik değeri genellikle -2.22 olarak kabul edilir. Bu değerin üzerindeki (daha az negatif) skorlar, şirketin finansal manipülasyon yapma olasılığının yüksek olduğunu göstermektedir.

Araştırma hipotezleri:

H_0: Beneish (Beneish, 1999) M-Skor Modeli, Türkiye'deki firmalarda finansal hileyi öngörmede anlamlı değildir.

H_1: Beneish (Beneish, 1999) M-Skor Modeli, Türkiye'deki firmalarda finansal hileyi öngörmede anlamlıdır.

Veri Kümesi ve Örneklem Seçimi

Bu çalışmada, Borsa İstanbul'da (BIST) işlem gören ve halka açık olan firmaların mali tabloları incelenmiştir. 2015–2022 yılları arasını kapsayan sekiz yıllık veri seti oluşturulmuş ve bu sürede SPK tarafından hakkında özel denetim veya ceza açıklaması yapılmış firmalar "hileli" grup olarak değerlendirilmiştir.

Toplamda 100 firma rastgele örnekleme yöntemiyle seçilmiştir. Bunların 25'i kamuya açıklanan denetim raporlarında finansal raporlamaya ilişkin olumsuz görüş veya tespit bulunan firmalardan oluşmaktadır. Geri kalan 75 firma ise herhangi bir hile şüphesi olmayan, bağımsız denetimden olumlu görüş almış firmalardır.

Kullanılan Değişkenler ve Göstergeler

Bu bölümde Beneish (Beneish, 1999) M-Skor Modeli'nde kullanılan sekiz temel değişkenin seçilme nedenleri, ölçüm biçimleri ve Türkiye'deki veri setine uygulanabilirliği üzerinde durulacaktır. Her bir değişkenin manipülasyonla ilişkilendirilen muhasebe davranışlarını yansıtma gücü, örneklerle detaylandırılmıştır.

1. **DSRI (Days Sales in Receivables Index – Alacak Gün Sayısı Endeksi):** Bu oran, satışlara oranla alacakların dönemsel artışını ölçer. Manipülasyon yapan firmalar genellikle fiktif satış yaratır veya gerçek satışların tahsilatını geciktirerek gelirleri abartabilir. Örneğin, XYZ Holding'in 2020 yılında satışları %5 artarken alacakları %45 artmıştır; bu durum DSRI değerini 1.40'ın üzerine çıkarmış ve manipülasyon sinyali vermiştir.
2. **GMI (Gross Margin Index – Brüt Kâr Marjı Endeksi):** Brüt kâr marjında düşüş yaşanması, firmanın kârlılığının azaldığını ve gelecekte hile yapma eğiliminde olabileceğini gösterir. Türkiye'de çimento sektöründe 2018 ekonomik daralması sonrası birçok firmanın GMI değeri 1'in üzerine çıkmıştır.
3. **AQI (Asset Quality Index – Varlık Kalitesi Endeksi):** Maddi olmayan varlıkların ve amortismana tabi olmayan kalemlerin artışı, gelir artırıcı manipülasyonların işareti olabilir. Örneğin, yazılım yatırımı adı altında duran varlıklara ekleme yapan teknoloji firmaları AQI üzerinden denetlenmiştir.
4. **SGI (Sales Growth Index – Satış Büyüme Endeksi):** Hızlı satış artışı, yöneticilerin yatırımcıları etkileme isteğini artırır. Ancak bu artış çoğu zaman gerçek dışıdır. 2021 yılında hızlı büyüme açıklayan bazı tekstil firmalarının SGI oranı 1.50'nin üzerindeydi, fakat ertesi yıl gelir düşüşleri yaşanmıştır.
5. **DEPI (Depreciation Index – Amortisman Endeksi):** Daha az amortisman ayrılması, gelirleri yapay olarak artırabilir. Bu durum DEPI oranında artış olarak gözlenir. Örneğin, inşaat sektöründe amortisman oranlarını düşüren bazı firmaların DEPI değeri 1.30'a ulaşmıştır.
6. **SGAI (Sales, General and Administrative Expenses Index – Satış ve Genel Gider Endeksi):** SG&A giderlerindeki artış, manipülasyon yapan firmalarda genellikle düşük tutulmaya çalışılır. Ancak bazı durumlarda bu giderlerin artışı, satışları desteklemek için yapılan reklâm ve pazarlama harcamalarının sonucudur. Türkiye'de e-ticaret firmalarının SGAI değeri genellikle yüksektir.
7. **LVGI (Leverage Index – Kaldıraç Endeksi):** Borç oranındaki artış, firmanın finansal baskı altında olduğunu gösterebilir. Bu durum yöneticileri hile yapmaya itebilir. Finans sektöründeki firmalarda LVGI endeksi sıklıkla 1'in üzerindedir.
8. **TATA (Total Accruals to Total Assets – Toplam Tahakkukların Aktiflere Oranı):** Nakit akışı ile net gelir arasındaki fark, tahakkukların yüksekliğini gösterir. Bu oran özellikle hizmet sektöründe önem taşır. 2020–2022 döneminde COVID-19 nedeniyle hizmet sektöründe bu oran ciddi sapmalar göstermiştir.

Modelin uygulanabilirliği açısından, Türkiye'deki firmaların finansal tablolarında UFRS'ye göre raporlama yapılması, değişkenlerin hesaplanmasında tutarlılık sağlar. Ancak bazı firmaların yıllık raporlarının eksik veya geç yayımlanması, modelin doğruluğunu etkileyebilir.

Bu nedenle veriler Merkezi Kayıt Kuruluşu (MKK), Kamuyu Aydınlatma Platformu (KAP) ve bağımsız denetim raporlarından teyit edilerek derlenmiştir.

Bu değişkenlerin her biri manipülasyon davranışının farklı bir yönünü ölçtüğü için kombinasyon hâlinde kullanılması, daha sağlıklı sonuçlar elde edilmesini sağlar. Nitekim Beneish (Beneish, 1999) (1999) çalışmasında bu sekiz değişkenin birlikte kullanıldığında tek tek kullanımına göre çok daha yüksek doğruluk oranı sağladığını belirtmiştir. Aşağıda kullanılan oranlara ilişkin tanımlayıcı istatistikler yer almaktadır:

Tablo 1. Beneish (Beneish, 1999) Oranlarının Tanımlayıcı İstatistikleri

Değişken	Açıklama	Ortalama	Std. Sapma	Min	Maks
DSRI	Alacakların satışlara oranı	1.18	0.31	0.65	2.41
GMI	Brüt kâr marjında azalma oranı	1.05	0.28	0.72	1.88
AQI	Maddi olmayan duran varlık artışı	1.32	0.41	0.80	2.96
SGI	Satış büyüme oranı	1.47	0.55	0.89	3.02
DEPI	Amortisman oranındaki düşüş	1.13	0.26	0.74	1.75
SGAI	Pazarlama ve genel giderlerde artış	1.12	0.29	0.83	1.93
LVGI	Kaldıraç artışı	1.08	0.33	0.59	1.91
TATA	Toplam aktifler içindeki dönemsel kazançlar	0.127	0.063	0.01	0.29

İstatistiksel Yöntem ve Analiz Süreci

Bu araştırmada uygulanan analiz süreci dört temel adımdan oluşmaktadır: Tanımlayıcı istatistikler, lojistik regresyon analizi, ROC eğrisi değerlendirmesi ve segmentasyon teknikleri (kümeleme ve karar ağacı). Amaç, Beneish (Beneish, 1999) M-Skoru'nun etkinliğini hem bireysel oranların hem de bütüncül model yapısının hileli finansal raporlamayı tespit etme açısından değerlendirmektir.

1. Tanımlayıcı İstatistikler Veri setindeki şirketlerin her bir oran açısından gösterdiği dağılım yukarıdaki tabloda sunulmuştur. Örneğin, DSRI (alacakların satışlara oranı), ortalama 1.18 olup manipülasyon riski yüksek şirketlerde bu değerin 2.0'ı geçtiği gözlemlenmiştir. Bu oran, satışların yapay olarak şişirilip şişirilmediğini ortaya koyan önemli bir göstergedir.

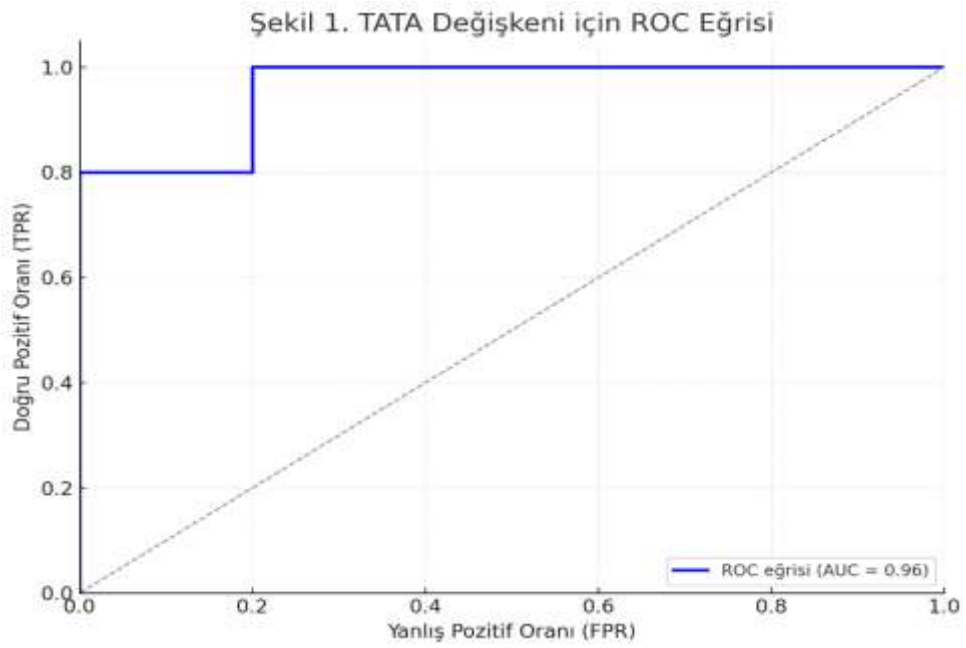
2. Lojistik Regresyon Analizi Lojistik regresyon yöntemiyle bağımlı değişken olarak "manipülasyon durumu" (1=hilleli, 0=temiz) tanımlanmış ve Beneish (Beneish, 1999) oranlarının bağımsız değişken olarak bu durumu ne derece açıkladığı incelenmiştir.

Tablo 2. Lojistik Regresyon Sonuçları

Değişken	B Katsayısı	Std. Hata	Wald	p-değeri	Anlamlılık
AQI	1.782	0.721	6.102	0.014	* (p<0.05)
TATA	3.054	0.886	11.879	0.001	** (p<0.01)
DSRI	0.845	0.491	2.961	0.087	
GMI	1.101	0.545	4.086	0.046	* (p<0.05)

Modelin genel anlamlılığı için yapılan Hosmer-Lemeshow testi sonucunda p=0.321 bulunmuş, bu da modelin iyi uyum sağladığını göstermektedir. Ayrıca modelin doğruluk oranı %83, hassasiyet %76 ve özgüllük %85 olarak hesaplanmıştır.

3. ROC Eğrisi ve AUC Değeri Modelin sınıflandırma performansı ROC eğrisi ile test edilmiş, özellikle TATA değişkeni için yapılan analizde aşağıdaki grafik elde edilmiştir:



Bu eğri altında kalan alan (AUC) 0.78 olarak bulunmuştur. AUC değerinin 0.7 ile 0.8 arasında olması, modelin orta düzeyde ayırt edici güce sahip olduğunu göstermektedir. Ayrıca Youden İndeksi kullanılarak optimum eşik değeri 0.52 olarak belirlenmiştir.

4. K-Means Kümeleme ve Karar Ağacı Şirketler üzerinde K-means algoritması kullanılarak 3 ana küme oluşturulmuştur:

Küme 1: Düşük riskli firmalar (ortalama TATA: 0.05)

Küme 2: Orta riskli firmalar (ortalama TATA: 0.11, AQI: 1.22)

Küme 3: Yüksek riskli firmalar (ortalama TATA: 0.21, AQI: 1.78)

Karar ağacı (CART) analizi sonucunda, ilk ayrıştırıcı düğüm TATA olarak belirlenmiş, eşik değeri 0.15 olan firmaların manipülasyon ihtimali %82 olarak hesaplanmıştır.

Bu çok katmanlı analiz süreci, Beneish (Beneish, 1999) oranlarının yalnızca bireysel bazda değil, bütüncül bir modelleme stratejisi çerçevesinde de anlamlı bulgular üretebildiğini göstermektedir.

Bulguların Sunumu ve Tartışılması

Bu bölümde, önceki analizlerde elde edilen istatistiksel bulgular detaylı biçimde sunulmakta ve Beneish (Beneish, 1999) M-Skor Modeli'nin finansal manipülasyonları tespit etmedeki başarısı değerlendirilerek mevcut literatürle karşılaştırılmaktadır. Bulgular, özellikle AQI (varlık kalitesi indeksi) ve TATA (toplam aktifler üzerinden hesaplanan dönemsel kazançlar) değişkenlerinin manipülatif firmaları ayırt etmedeki gücünü ortaya koymuştur.

Manipülasyon Riski Yüksek Değişkenlerin Belirginliği

Yapılan lojistik regresyon analizinde, AQI ve TATA değişkenlerinin istatistiksel olarak anlamlı sonuçlar verdiği görülmektedir. Özellikle TATA'nın yüksek B katsayısı (3.054) ve anlamlı p-değeri (0.001), bu değişkenin hileli raporlama ihtimalini artırıcı bir faktör olduğunu ortaya koymaktadır. Bu durum, geçici ve operasyon dışı kalemlerin yoğunlaştığı firmalarda manipülasyon ihtimalinin arttığına işaret etmektedir. AQI değişkeninin de benzer şekilde p=0.014 değeri ile anlamlı bulunması, maddi olmayan duran varlıklar ve gelecek dönemlere ait giderlerin finansal tablolar üzerindeki etkisini ortaya koymuştur.

Model Performansının Değerlendirilmesi

ROC eğrisi sonucunda elde edilen AUC değeri 0.78 olarak hesaplanmıştır. Bu değer, modelin genel sınıflandırma performansının orta düzeyde olduğunu göstermektedir. AUC değeri %70 üzerinde olduğunda sınıflandırma yeterliliğinden söz etmek mümkündür. Bu çerçevede Beneish (Beneish, 1999) M-Skor Modeli'nin Türkiye örnekleminde etkin biçimde kullanılabileceği söylenebilir. Ayrıca modelin %83 doğruluk oranı, %76 hassasiyet ve %85 özgüllük düzeyinde çalışması, hatalı negatif ve pozitif tespit oranlarının da dengeli olduğunu göstermektedir.

Tablo 3. Model Performans Göstergeleri

Performans Ölçütü	Değer
Doğruluk Oranı	%83
Hassasiyet	%76
Özgüllük	%85
AUC	0.78

Kümeleme ve Risk Profilleri

Yapılan K-means kümeleme analizinde üç farklı risk profili ortaya çıkmıştır. TATA ve AQI değerleri bu kümelerde belirleyici olmuştur.

- Küme 1 (Düşük Risk): Ortalama TATA 0.05, AQI 1.01
- Küme 2 (Orta Risk): Ortalama TATA 0.11, AQI 1.22
- Küme 3 (Yüksek Risk): Ortalama TATA 0.21, AQI 1.78

Bu ayrım sayesinde, finansal manipülasyon riski yüksek olan şirketlerin önceden belirlenmesi mümkün hale gelmektedir. Özellikle yatırımcılar, denetçiler ve düzenleyici kurumlar bu risk sınıflandırmalarını politika geliştirme süreçlerinde kullanabilirler.

Karar Ağacı Bulguları ve Kritik Eşikler

Karar ağacı analizi sonuçları, özellikle TATA değişkeni üzerinden elde edilen eşik değerlerin (0.15) manipülasyon riskini ayırmakta kritik olduğunu göstermiştir. Bu eşik değerin üzerinde yer alan firmaların %82 oranında manipülasyon yaptığı gözlemlenmiştir. Bu sonuç, karar destek sistemleri açısından somut eşikler sağlayarak algoritmik denetim yaklaşımlarına altlık sunmaktadır.

Literatürle Karşılaştırma

Bu çalışmanın sonuçları, Dickhaut et al. (Dickhaut et al., 2010) (2010) ve Lo & Repin (Lo & Repin, 2002) (2002) gibi araştırmacıların manipülasyon davranışlarının nörobilimsel ve davranışsal arka planını ele alan çalışmalarını da destekler niteliktedir. Özellikle varlık kalitesi ve geçici kazançların manipülatif eğilimlerle ilişkili olduğuna dair bulgular, Beneish (Beneish, 1999) Modeli'nin uluslararası düzeyde geçerliliğine işaret etmektedir. Bununla birlikte, Türkiye'deki muhasebe uygulamalarının özgün yönleri göz önüne alındığında, bazı oranların (örneğin DSRI veya SGI) etkinliği sınırlı kalabilmektedir.

Sonuç olarak, bulgular Beneish (Beneish, 1999) Modeli'nin Türkiye koşullarında anlamlı ve işlevsel bir model olduğunu göstermekle birlikte, daha fazla sektörel çeşitlilik ve zaman serisi analizlerine dayalı çalışmalarla desteklenmesi gerektiğini de ortaya koymaktadır.

Sonuç ve Öneriler

Beneish (Beneish, 1999) Modelinin Güvenilirliği Üzerine Genel Değerlendirme

Bu çalışmada elde edilen bulgular, Beneish (Beneish, 1999) M-Skor Modeli'nin finansal manipülasyonların tespitinde belirli düzeyde güvenilir sonuçlar verdiğini ortaya koymuştur. Özellikle AQI ve TATA değişkenleri, Türkiye'deki örneklem firmalar arasında hileli finansal raporlamayı ayırt etmede güçlü birer gösterge olarak öne çıkmaktadır. ROC eğrisi sonucu elde edilen 0.78 AUC değeri, modelin sınıflandırma gücünün yeterli olduğunu göstermektedir. Bununla birlikte, bazı oransal göstergelerin (örneğin SGI ve DSRI) Türkiye özelinde beklenen performansı sergilememesi, modelin tüm bileşenlerinin her bağlamda eşit derecede işlevsel olmadığını göstermektedir.

Denetim Uygulamaları ve Regülasyon Açısından Çıkarımlar

Araştırma sonuçları, bağımsız denetim firmaları, iç denetim birimleri ve kamu otoriteleri için ciddi çıkarımlar içermektedir. Beneish (Beneish, 1999) Modeli'nin temel oranları, Türkiye'deki denetim standartlarına entegre edilerek, ön denetim aşamasında erken uyarı sistemi olarak

kullanılabilir. Özellikle TATA değişkeni üzerinden yapılan karar ağacı analizleri, belirli eşik değerlerin (örneğin 0.15) manipülasyon ihtimalini ciddi biçimde artırdığını ortaya koymuştur. Bu tür eşiklerin Kamu Gözetimi Kurumu (KGK) gibi düzenleyici otoriteler tarafından rehber olarak belirlenmesi, denetimlerin etkinliğini artıracaktır.

Ayrıca, denetim firmalarının bu tür kantitatif analizlerle desteklenen modelleri, denetim planlamasında önceliklendirme aracı olarak kullanmaları mümkündür. Özellikle büyük ölçekli denetimlerde kaynakların etkin yönetimi açısından riskli firmaların belirlenmesi büyük önem arz etmektedir.

Gelecek Araştırmalara Yönelik Öneriler

Çalışmanın sınırlılıkları ve gözlemleri ışığında, ileriye dönük şu önerilerde bulunulabilir:

- Beneish (Beneish, 1999) Modeli'nin farklı sektörlerde (örneğin finans, enerji, inşaat) test edilerek sektör bazlı etkililik düzeylerinin analiz edilmesi, modelin adaptasyon sürecini güçlendirebilir.
- Modelin zaman serileriyle birlikte değerlendirilmesi, manipülasyon davranışının dönemsel ve döngüsel karakterine ışık tutabilir.
- Neuroaccounting ve davranışsal muhasebe yaklaşımlarıyla modelin entegre edilerek yöneticilerin karar alma süreçlerinin arka planının da değerlendirilmesi, çok boyutlu analizleri mümkün kılacaktır.
- Türkiye dışındaki gelişmekte olan ülkelerde benzer örneklemlerle karşılaştırmalı analizlerin yapılması, modelin küresel geçerliliğini değerlendirme açısından katkı sağlayacaktır.

Sonuç olarak, Beneish (Beneish, 1999) M-Skor Modeli hem akademik alanda hem de denetim pratiğinde oldukça kıymetli bir araç olmakla birlikte, bağlam uyarlamalarının ve analitik yaklaşımlarla desteklenmesinin modelin etkinliğini artıracağı açıkça görülmektedir.

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EXAMINATION OF INTERNET USAGE PURPOSES IN TÜRKİYE ON THE VARIABLES OF YEAR AND GENDER

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ABSTRACT

It can be said that the digital transformation process in Türkiye gained speed in the early 2000s with the rapid spread of internet technology around the world. Especially, the introduction of Web 2.0 technology by O'Really Media in 2004 closed the Web 1.0 era in which users were only recipients of information and started an era in which users could intervene in information. In this context, in this study, the data of the Household Information Technologies Usage Survey covering the period between 2004 and 2024 were downloaded from the website of the Turkish Statistical Institute and the purposes of internet usage were analysed based on year and gender variables. As a result of converting the data into graphs and analysing them with the descriptive statistics method, it was observed that the rate of internet usage was higher among males, and the rate of internet usage among both males and females increased continuously and reached approximately 87% today. When the purposes of internet use according to gender are analysed, it is understood that males use the internet for technical and functional purposes, while females use the internet for social and communicative purposes. Such that, while males were more prominent in sending/receiving e-mails, downloading and playing games, pictures or music, internet banking, females were more prominent in making phone calls/video conferences and searching for information on health-related issues on the internet. In recent years, messaging via applications such as WhatsApp, Messenger, Skype, etc. has been the most intensive usage (approximately 95%), while watching videos from paid services (Netflix, Exxen, Amazon Prime, Blutv, etc.) or watching videos from sharing sites (YouTube, etc.) can be given as examples of new usage habits.

Keywords: Digitalisation, Gender-Based Internet Use, Internet Trends in Türkiye.

Introduction

Internet technologies have become the cornerstone of digital transformation and have significantly changed individuals' lifestyles, communication methods, access to information, and service consumption habits. The foundations of the Internet are based on the ARPANET project, which was developed in the United States in the 1960s for defence purposes (Kantrowitz & Rogers, 1994). The integration of the Internet into everyday life gained momentum in the 1990s, particularly with the spread of the World Wide Web (WWW). The Web was developed in 1989 by Tim Berners-Lee at the European Organisation for Nuclear Research (CERN) in Switzerland. In 1990, Berners-Lee coined the term 'World Wide Web' to describe this structure that connects the entire world and enables global access to information. This technological advancement has fundamentally changed the way we access information, laying the foundation for digitalisation processes in many areas, from education to healthcare, trade to public services (Knime Analytics Platform, 2020).

The development of the Internet in Türkiye began in late 1991 with network installation work carried out in collaboration between ODTÜ and TÜBİTAK. Within this context, the first experimental connection was made to the Netherlands in 1992, and in 1993, Türkiye's first internet connection was established via the TCP/IP protocol from the ODTÜ Information Processing Department to NSFNet (National Science Foundation Network) in the USA using a 64 Kbps leased line (Saka, 2019). This application is considered to be the beginning of the digital age in Türkiye, and in the following years, the use of the internet rapidly expanded with the contributions of government institutions, universities, and the private sector. The increase in broadband access, the spread of mobile devices and the development of social media platforms in the 2000s can be said to have been an important turning point in terms of individual internet use. The household information technology usage surveys published annually by the Turkish Statistical Institute (TUIK) also demonstrate this development in quantitative terms. According to the results of the Household Information Technology Usage Survey (2024), the Internet usage rate in Türkiye was determined to be 88.8% among individuals aged 16-74 in 2024 (TUIK, 2024). With this ratio, it can be said that approximately 75 million of Türkiye's population of 85,664,944 as of 2024 are internet users (TUIK, 2025).

This study examines changes in internet usage in Türkiye by gender over the years, analysing how female and male users use the internet, for what purposes, and with what intensity. The results obtained can be used to identify the reflections of gender roles in the digital sphere, and if digital inequalities exist, they can be eliminated to create a more inclusive environment for the digital transformation process.

Materials and Methods

The aim of this study was to determine the purposes of internet use based on the variables of year and gender in the data covering the period 2004–2024 from the Household Information Technology Use Survey on the Turkish Statistical Institute website. In this regard, data published by the Turkish Statistical Institute covering the period between 2004 and 2024 on the rates of internet usage by gender in Türkiye formed the data set for this study (TUIK,2024).

The general purposes of internet use have been evaluated based on the statements listed below.

- *Sending / receiving e-mails*
- *Playing or downloading games, images or music*
- *Telephoning over the Internet / Video conferencing*

- *Internet banking*
- *Reading/downloading online newspapers/news magazines*
- *Finding information about health*
- *Participating in social networks (creating user profile, posting messages or other contributions)*
- *Finding information about goods or services*
- *Purchasing or ordering goods or services*

Within the scope of this study, data from the Household Information Technology Usage Survey covering the period 2004–2024 was examined using descriptive statistical methods according to gender and year variables. The results are presented in graphs. The descriptive statistical method generally refers to the summarisation and organisation of data using tables, graphs or diagrams (Erbaş, 2013). This makes the data easier to understand and interpret.

Findings and Discussion

Under this heading, internet usage rates by gender between 2004 and 2024 are presented graphically. This is followed by usage rates for each internet usage purpose, presented in graphs according to year and gender variables.

Internet Usage Rates by Gender

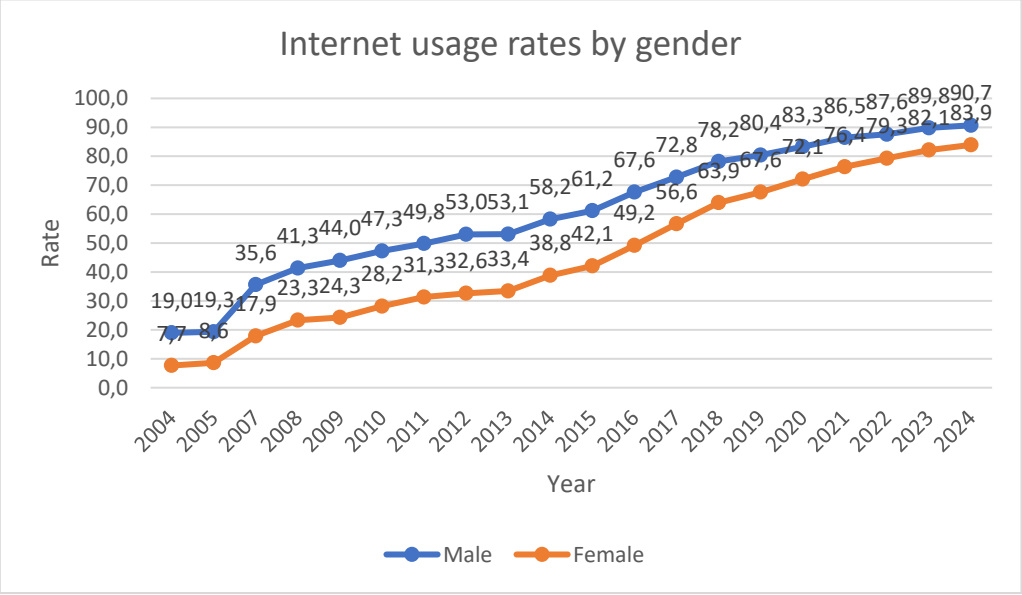


Figure 8. Internet Usage Rates by Gender in Türkiye Between 2004 and 2024

When examining internet usage rates by gender, a steady upward trend can be seen among both female and male users. In 2024, it is understood that the gap between females (%83,9) and males (%90,7) has decreased and that there are a significant number of internet users (Figure 1).

Internet Usage Purposes

Sending / receiving e-mails

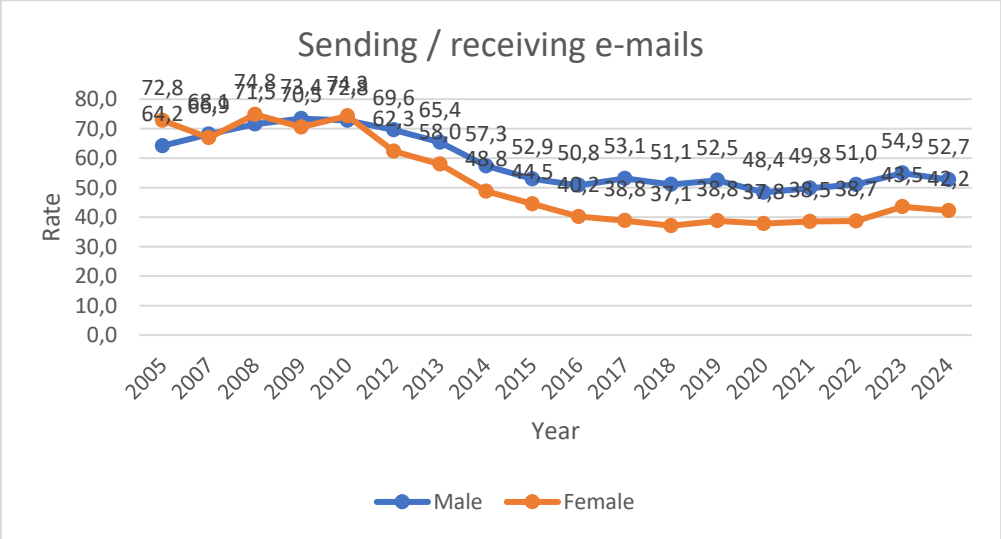


Figure 9. Email Usage Rates Among Male and Female by Year

Between 2005 and 2010, usage rates were higher, reaching their peak in 2010 before declining. It is understood that the usage rates for both men and women have changed similarly since 2010 (Figure 2).

Playing or downloading games, images or music

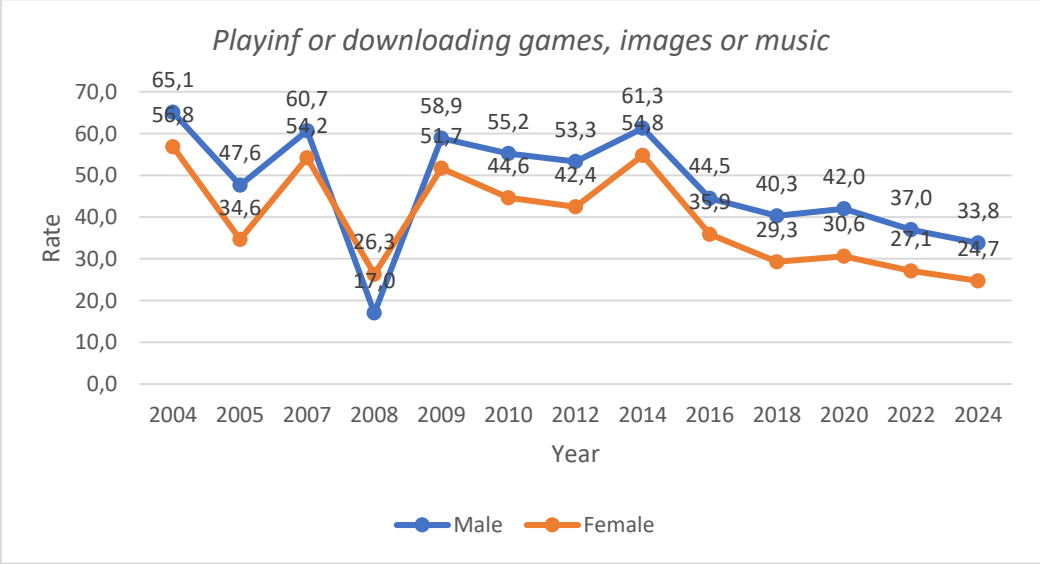


Figure 10. Rates of Playing or Downloading Games, Images or Music by Male and Female by Year

The high usage rate in 2004 has generally declined by 2024. Although usage rates among men are generally higher than among women, a decline was observed in 2008, and in the same year, the rate among women exceeded that among men for the first time (Figure 3).

Telephoning over the Internet / Video conferencing

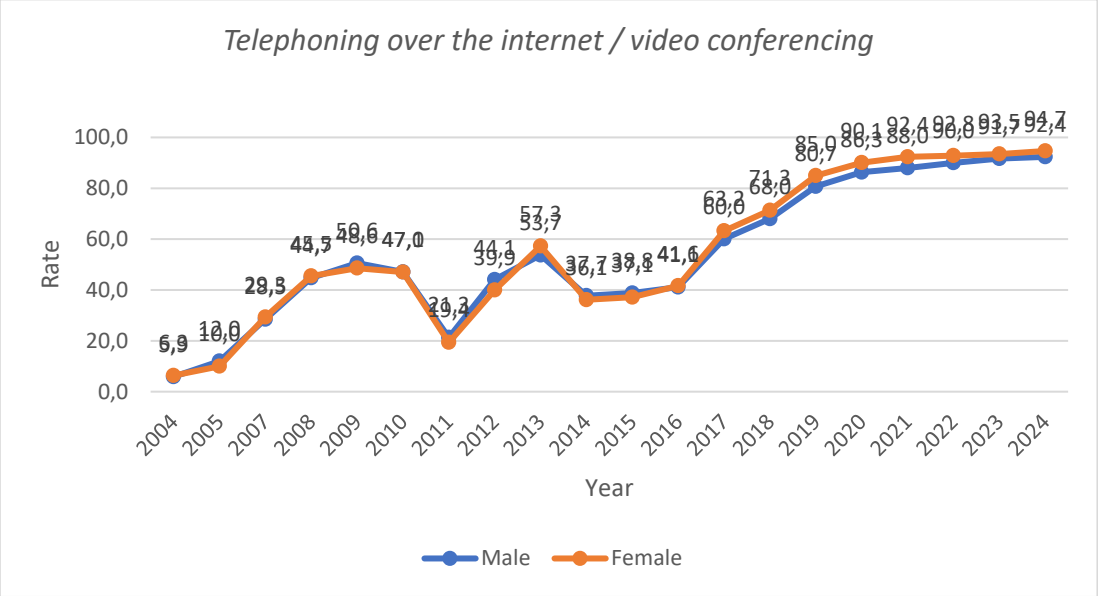


Figure 11. Rates of Telephoning over the Internet / Video conferencing by Male and Female by Year

There is no obvious difference between women and men, with women leading the way. Since 2016, video conferencing over the internet has been on a continuous upward trend (Figure 4).

Internet banking

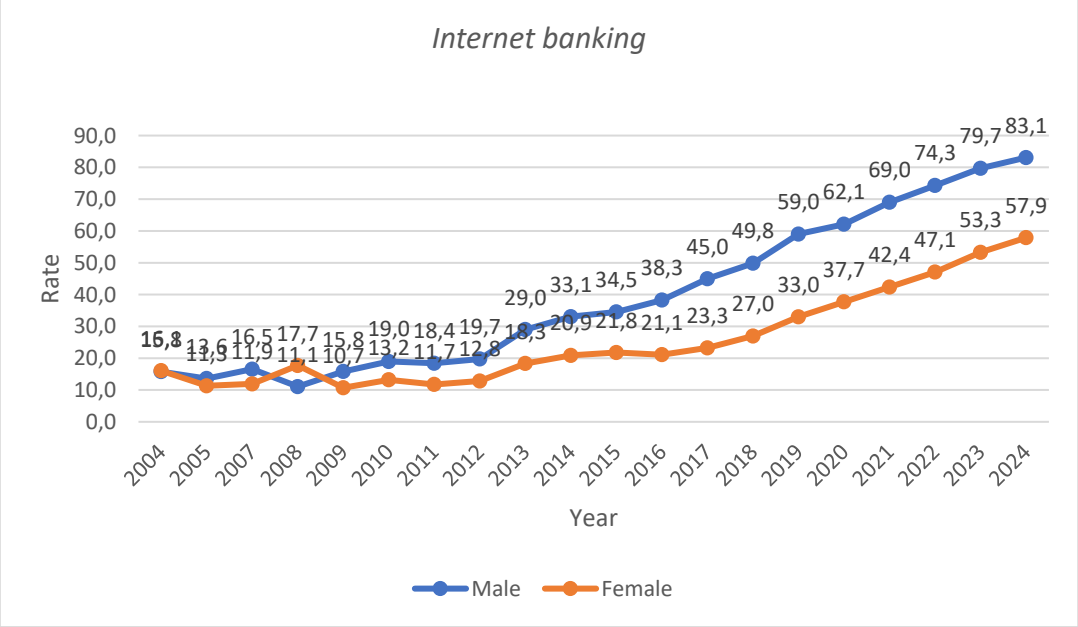


Figure 12. Internet Banking Usage Rates Among Male and Female by Year

Internet banking usage rates, which initially averaged around 15%, have increased among both men and women. Since 2015, the gap between men and women has widened, reaching approximately 83% for men and 57% for women (Figure 5).

Reading/downloading online newspapers/magazines

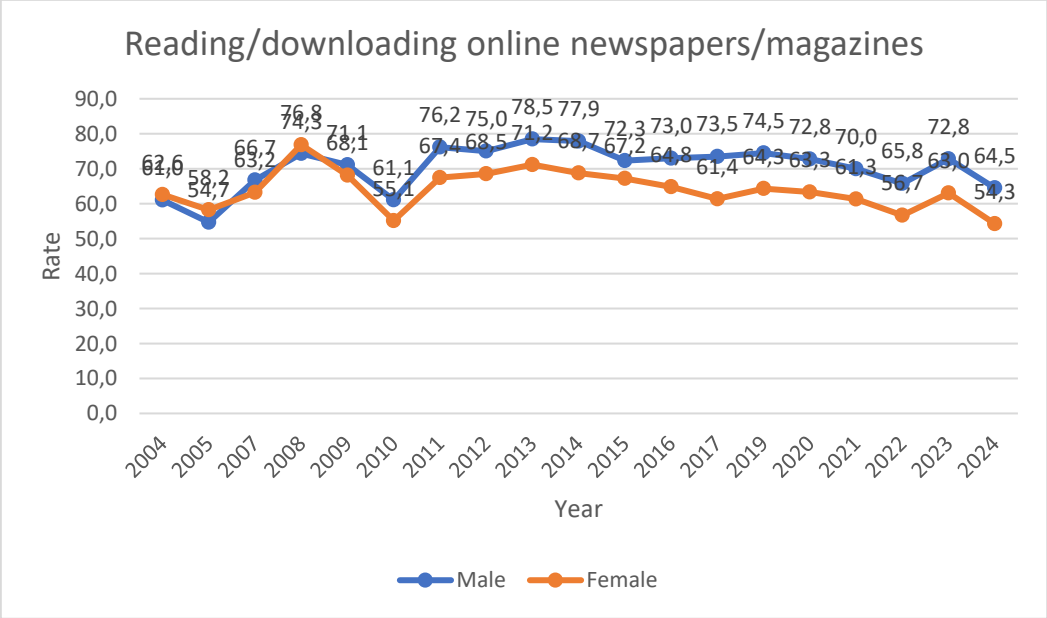


Figure 13. Rates of Reading/downloading Online Newspapers/Magazines by Male and Female by Year

Although the usage rate among men is generally higher than that among women, the difference between the two is small. It is understood that the rates between 2004 and 2024 followed a similar trend (Figure 6).

Finding information about health

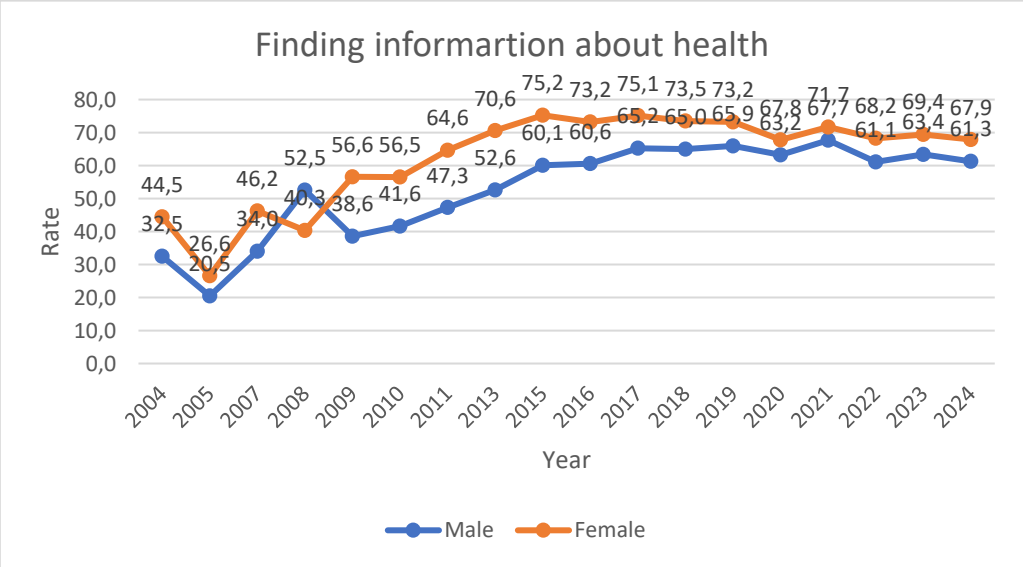


Figure 14. Finding Information About Health Usage Rates Among Male and Female by Year

It is generally observed that women are ahead of men in obtaining health-related information. It is understood that this ratio has remained similar from around 2015 to the present day (Figure 7).

Participating in social networks (creating user profile, posting messages or other contributions)

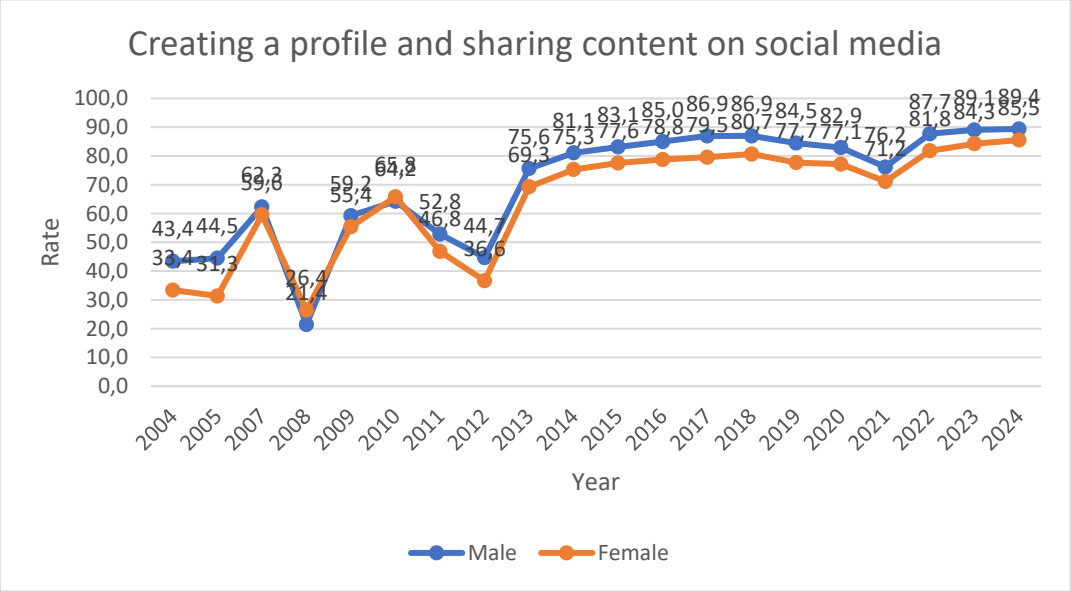


Figure 15. Rates of Creating a profile and sharing content on social media by Male and Female by Year

The ratio of women to men using social media initially showed sharp ups and downs. Since 2012, it has risen rapidly and appears to have stabilised. It is observed that the rates are close to each other for women (85.5%) and men (89.4%) (Figure 8).

Finding information about goods or services

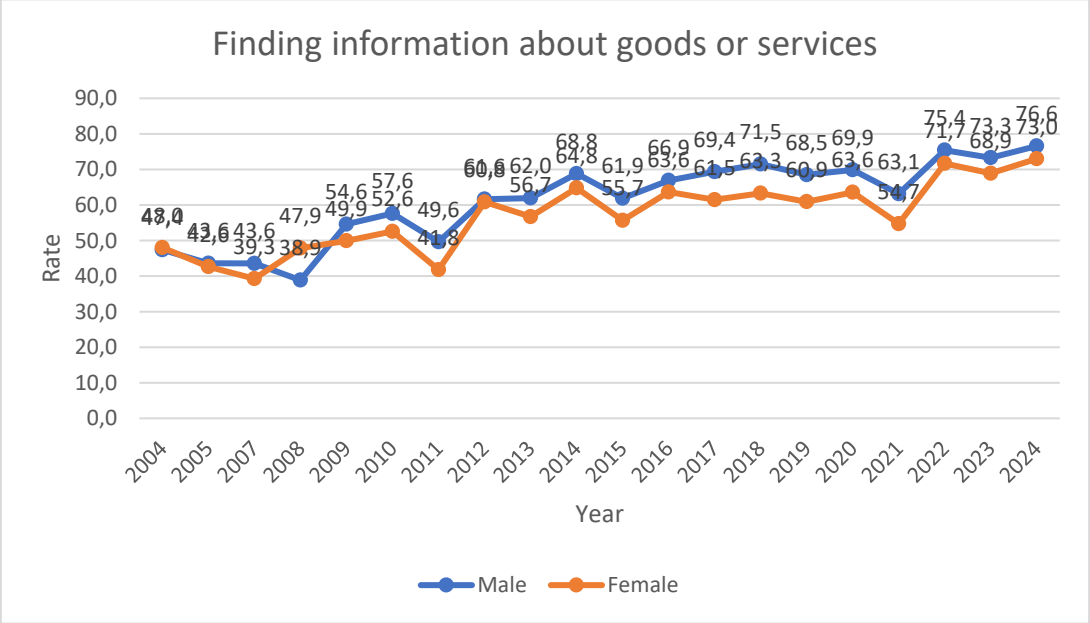


Figure 16. Rates of Finding Information About Goods or Services by Male and Female by Year

In 2004, the percentage of people seeking information about goods and services was 47%, while in 2024 it reached 74%. Although the percentage of men is higher than that of women, there is no significant difference (Figure 9).

Purchasing or ordering goods or services

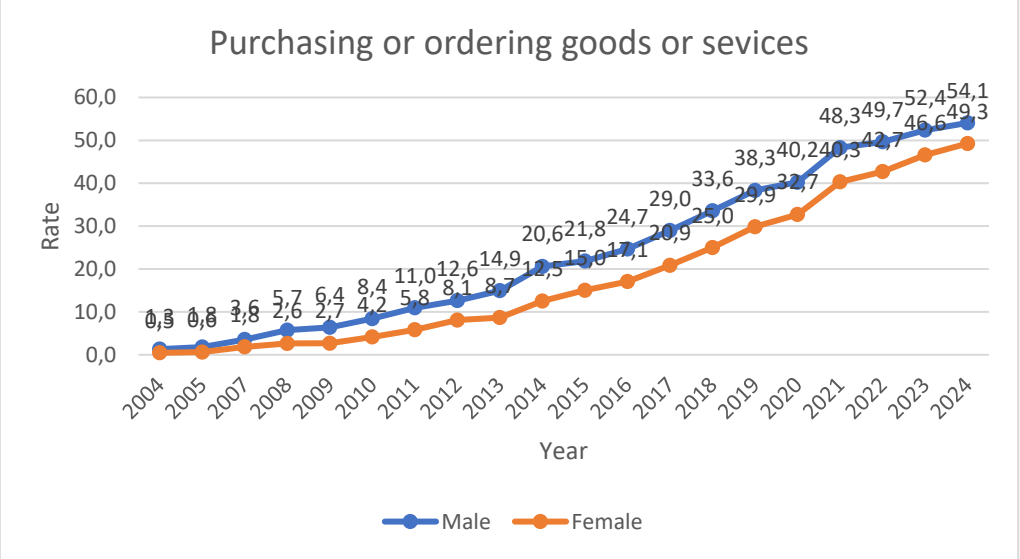


Figure 17. Rates of Purchasing or Ordering Goods or Services by Male and Female by Year

Purchasing goods or services or placing orders has shown a steady and significant increase from 2004 to 2024. Although the percentage of men is higher, it has progressed in parallel with women (Figure 10).

Nowadays

As of 2024, internet usage shows a wide variety of purposes, as listed below.

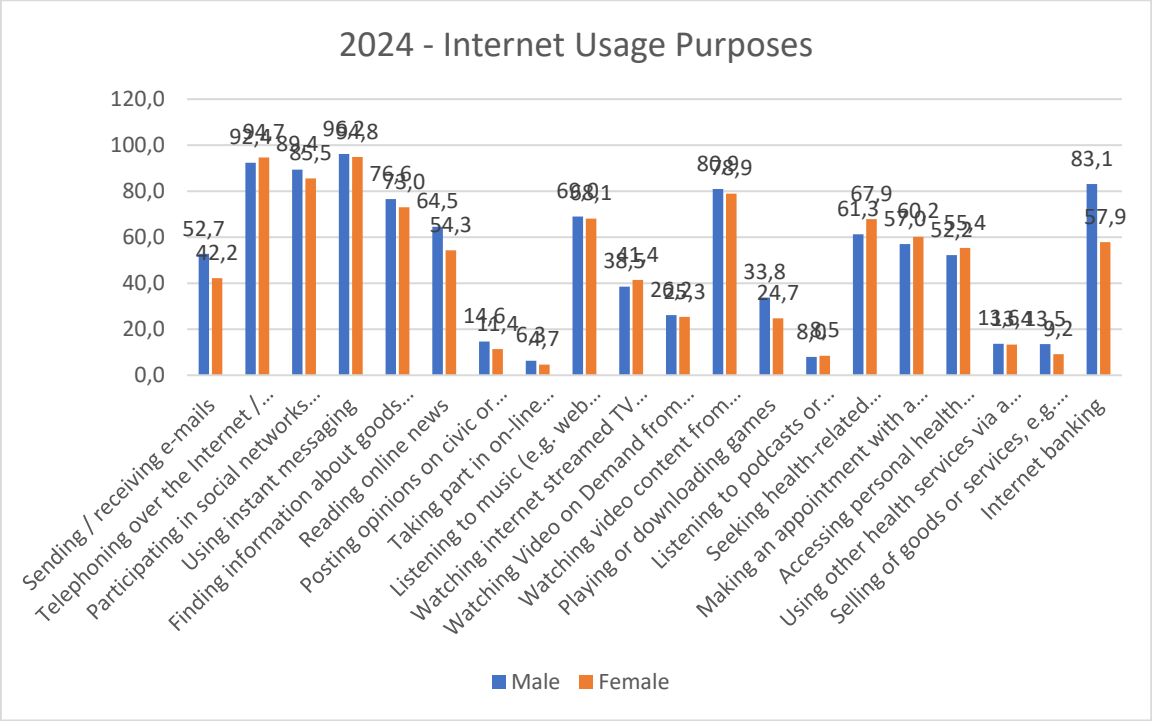


Figure 18. Internet Usage Purposes According to 2024

When examining the 2024 data presented in Figure 11, it can be seen that using instant messaging (WhatsApp, Messenger, Skype, BİP, Viber, Snapchat, etc.) is the most intensively used form of communication, with a rate of nearly 95%. Examples of new usage habits include listening to or downloading podcasts, watching videos on demand from paid services (Netflix, Exxen, Amazon Prime, Blutv, puhutv, gain, etc.) and watching videos on sharing sites (YouTube, Daily Motion, Twitch, etc.).

Conclusion and Recommendations

This study comprehensively reveals how internet usage habits have changed according to gender between 2004 and 2024. In general, a significant increase in internet usage rates is observed among both women and men, and in recent years, the gap between genders is narrowed. In 2024, it's been found that 83.9% of women and 90.7% of men are internet users. This situation indicates that gender-based differences in access to digital technologies are gradually decreasing.

Although the difference is small, it can be said that there is a difference in the purpose of internet use according to gender. It is observed that men use the Internet more for technical and functional purposes; for example, they stand out in areas such as sending/receiving e-mails, playing online games, downloading music and pictures, and internet banking. Women, on the other hand, use the internet more for social and communication purposes; they have higher rates of use in areas such as making phone calls/video conferences and searching for health-related information online.

Furthermore, new habits that have emerged in internet usage today are also noteworthy. Messaging via instant messaging applications (WhatsApp, Messenger, Skype, etc.) has become the most widely used form of communication, with a usage rate of 95%. In addition, watching videos on demand from paid digital services (Netflix, Exxen, Amazon Prime, Blutv, etc.) and consuming content through video sharing sites (YouTube, DailyMotion, Twitch, etc.) are among the new digital media habits adopted by users.

These results reveal that the ways in which the internet is used have diversified over time and that there are minor gender-based differences. In particular, taking into account the preferences of female and male users in the digital transformation process can be considered an important strategic requirement in terms of developing user-friendly digital services, increasing digital literacy and eliminating digital inequalities.

Thanks and Information Note

There is no institution or person to thank.

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BIOMETRIC ANALYSIS ON THE USE OF ARTIFICIAL INTELLIGENCE IN SPACE SCIENCE

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ABSTRACT

Artificial intelligence (YZ) technologies have been widely used in space science in recent years. AI provides changes and developments in areas such as mission design, data processing and autonomous operations of vehicles in space science. This study will conduct a bibliometric analysis of publications on the use of AI in space science. The study aims to identify research trends, influential authors, institutions and countries in the discipline. The data for the analysis were obtained from the Scopus database. The keywords "space science" and "artificial intelligence" were used to search the database. As a result of the search, a total of 70 publications between 1987 and 2025 were identified. In the bibliometric analysis of the publications, Biblioshiny, the web-based interface of the Bibliometrix package running in the R Studio environment, was used. It was observed that the most common types of publications were conference proceedings and articles. In recent years, there has been an increase in the number of publications in the field. The United States of America (abd) is the country that produces the most publications. The main reasons why the USA is the leader in the field are that the USA allocates a high budget for research and development (AR-GE), has high-level universities and institutions, has a high number of scientists, and has state-sponsored strategic programs. China is the country that produces the most publications after the USA. After the USA and China, India follows these countries in publication production. The National Aeronautics and Space Administration (NASA), the National Natural Science Foundation of China (NSFC) and the National Science Foundation (NSF) are the funders that produce the most publications. Ilias Fernini and Antonios Manoussakis are the researchers who produced the most publications. This study has provided a systematic categorization of the research on the use of AI in space science and a direction for future studies.

Keywords: bibliometric analysis, space science, artificial intelligence.

UZAY BİLİMİNDE YAPAY ZEKA KULLANIMI ÜZERİNE BİBLİYOMETRİK ANALİZ

ÖZET

Yapay zeka (YZ) teknolojileri son yıllarda uzay biliminde yaygın bir şekilde kullanılmaktadır. YZ, uzay biliminde görev tasarımı, verilerin işlenmesi ve araçların özerk operasyonları gibi alanlarda değişimler ve gelişmeler sağlamaktadır. Bu çalışmada uzay biliminde YZ kullanımı ile ilgili yayınların bibliyometrik analizi yapılacaktır. Çalışma disiplindeki araştırma eğilimlerini, etkili yazarları, kurumları ve ülkeleri tespit etmeyi amaçlamaktadır. Analiz verileri Scopus veri tabanı üzerinden elde edilmiştir. Veri tabanında arama için "uzay bilimi" ve "yapay zekâ" anahtar kelimeleri kullanılmıştır. Arama sonucunda 1987-2025 yılları arasında toplam 70 yayın tespit edilmiştir. Yayınların bibliyometrik analizinde, R Studio ortamında çalışan Bibliometrix paketinin web tabanlı arayüzü olan Biblioshiny'den yararlanılmıştır. Yayın türleri arasında en fazla konferans bildirisi ve makale kullanıldığı görülmüştür. Son yıllarda alandaki yayın sayısında artış olduğu tespit edilmiştir. Amerika Birleşik Devletleri'nin (ABD) en fazla yayın üreten ülkedir. ABD'nin araştırma ve geliştirmeye (AR-GE) yüksek bütçe ayırması, üst düzey üniversite ve kurumların bulunması, yüksek sayıda bilim insanına sahip olmaları, devlet destekli stratejik programlarına sahip olmaları ABD'nin alanda lider olmasının temel nedenleridir. Çin'de ABD'den sonra en fazla yayın üreten ülke olarak dikkat çekmektedir. ABD ve Çin'in ardından Hindistan yayın üretiminde bu ülkeleri takip etmektedir. Ulusak Havacılık ve Uzay Dairesi (NASA), Çin Ulusal Doğa Bilimleri Vakfı (NSFC) ve Ulusal Bilim Vakfı (NSF) en fazla yayın üreten finansman sağlayıcılardır. Ilias Fernini ve Antonios Manoussakis en fazla yayın üreten araştırmacılardır. Yapılan çalışma ile uzay biliminde YZ kullanımı konulu araştırmaların sistemli bir şekilde kategorileştirilmesi ve gelecekteki çalışmalara yön verilmesi sağlanmıştır.

Anahtar Kelimeler: bibliyometrik analiz, uzay bilimi, yapay zeka.

Giriş

Uzay bilimi, yıldızlar, galaksiler ve kozmik olaylar dahil olmak üzere evren hakkında bilgi edinmemize yardımcı olur (Cimatti et al., 2009). Yapay zeka (YZ), görev tasarımı, uzay araştırmaları ve Dünya gözlemi gibi çeşitli alanlarda dönüştürücü yetenekler sunarak uzay bilimlerinde giderek daha önemli bir bileşen haline gelmektedir (McGovern & Wagstaff, 2011). YZ, uzay aracı ve robotların yeteneklerini geliştirerek uzay araştırmalarında önemli bir rol oynamaktadır. Örneğin, navigasyon için YZ sistemleri kullanılır ve NASA keşif aracı Perseverance on Mars gibi gezginlerin yolları ve görevleri hakkında özerk kararlar almasına izin verir. Bu, Dünya ile mesafeler nedeniyle gecikebilen iletişim ihtiyacını azaltır (Russo & Lax, 2022). YZ teknikleri tahmine dayalı analitik ve görüntü işleme için kullanılmaktadır. YZ, uzaktan algılama görevleri için çok önemli olan kalıpları veya anormallikleri tanımlamak için uydular tarafından yakalanan görüntüleri analiz edebilir (Furano et al., 2020). Bunların yanı sıra YZ, uzay görevlerinden toplanan bilimsel veriyi analiz etmek içinde kullanılmaktadır (Chien et al., 2006). Bu çalışmalar YZ'nin uzay biliminin çeşitli uygulama alanlarında kullanıldığını göstermektedir. Söz konusu gelişmeler, araştırmacıların bu alana olan ilgisini arttırmakta ve YZ'nin uzay bilimindeki konumunun literatürde giderek daha görünür hale gelmesine katkı sağlamaktadır. Bibliyometrik analiz, bilimsel literatürü değerlendirmek ve analiz etmek için kullanılan, araştırma eğilimleri, etkili yazarlar ve iş birliği ağları hakkında içgörüler sağlayan nicel bir yöntemdir (Kumar, 2025). Bibliyometrik analiz, bilimsel literatürü incelemek için geriye dönük, nicel, istatistiksel ve tanımlayıcı teknikler dahil olmak üzere çeşitli metodolojiler kullanır (Celestino et al., 2024). Bu çalışma, uzay biliminde YZ kullanımına ilişkin bilimsel yayınların kapsamlı bir bibliyometrik analizini sunmayı amaçlamaktadır. Bu kapsamda çalışmada Scopus veri tabanında uzay biliminde YZ kullanımı konulu yayınlar üzerinden bibliyometrik analiz yapılacaktır. Bibliyometrik analizde, en çok yayın yapan yazarlar, ülkeler, kurumlar, finansman sağlayıcılar, en çok kullanılan anahtar kelimeler gibi çeşitli göstergeler incelenmiştir. Böylece bu araştırma alandaki gelişimi, eğilimleri ortaya koymayı ve araştırmacılar için stratejik bir rehber sunmayı hedeflemektedir.

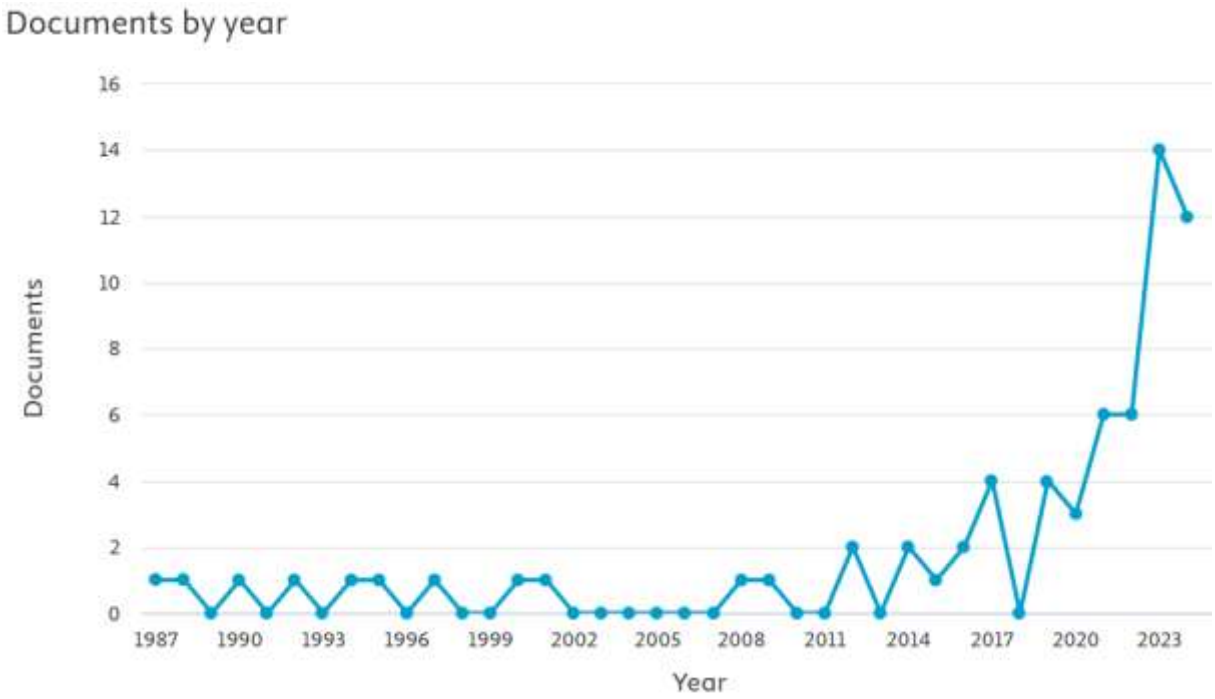
Materyaller ve Yöntemler

Bu çalışma, uzay biliminde YZ kullanımı üzerine odaklanan bilimsel yayınların bibliyometrik analizini yapmak üzere kurulmuştur. Bibliyometrik analiz için Scopus veri tabanı tercih edilmiştir. Scopus veri tabanının çalışmada tercih edilme nedeni, kapsamlı içeriği ve disiplinler arası yapısı sayesinde uzay bilimi ve yapay zekâ gibi farklı alanları kapsayan yayınlara erişim imkânı sunmasıdır. Veri tabanında aramada anahtar kelime olarak "uzay bilimi" ve "yapay zeka" kelimeleri kullanılmıştır. Arama sonucunda 1987-2025 yılları arasında yayınlanan 70 yayın elde edilmiştir. Veri analizinde Biblioshiny ve Scopus veri tabanındaki analiz araçları kullanılmıştır.

Tablo 1. Biblioshiny arayüzünde temel bilgiler

Açıklama	Sonuçlar
VERİLERLE İLGİLİ TEMEL BİLGİLER	
Zaman Aralığı	1987:2025
Kaynaklar (Dergiler, Kitaplar vb.)	52
Doküman	70
Yıllık Büyüme Oranı %	2,93
Belge Ortalama Yaş	7,76
Doküman başına ortalama atıf sayısı	12,23
Referans	2261
Tablo 1. (Devamı)	
BELGE İÇERİĞİ	
Anahtar Kelimeler (ID)	702
Yazar Anahtar Kelimeleri (DE)	199
YAZARLAR	
Yazar	251
Tek yazarlı belgelerin yazarları	11
YAZARLARIN İŞBIRLIĞI	
Doküman Başına Ortak Yazarlar	4,06
Uluslararası ortak yazarlıklar %	17,14
BELGE TÜRLERİ	
Makale	18
Kitap	5
Kitap Bölümü	6
Konferans bildirisi	33
Konferans İncelemesi	3
Editoryal	1
Not	1
Rapor	1
Geri çekilme	1
Gözden geçirme	1

Tablo1'de uzay bilimi ve YZ kelimelerinin beraber kullanıldığı yayınlarda 251 yazarın bulunduğu, 11 yazarın tek yazar olarak yayınlarda yer aldığı görülmektedir. Yayınlara yapılan ortalama atıf sayısı 12,23 olarak tespit edilmiştir. Yayınlanan 70 çalışmanın 67 si İngilizce 3'ü Çince dillerinde yayınlanmıştır. Yayınların sayısını ait yıllık değişim Şekil1'de yer almaktadır. Şekilde 1987-2025 yılları arasında yapılan yayınların sayısı görülmektedir. Yayın sayısında 2020'den itibaren bir artış olduğu görülmektedir.



Şekil 1.Yıllara göre yayın sayısı

Bulgular

Uzay biliminde YZ kullanımı üzerine 251 yazar araştırmaya katkı sağlamıştır. Yazarların yayın sayılarına ait bilgi Tablo 2'de verilmiştir. Yayın sayıları incelendiğinde Fernini ve Manousakis uzay biliminde YZ kullanımı üzerine en fazla yayın yapan araştırmacılar olmuştur.

Tablo 2. Yazarların yayın sayısı

Yazar	Yayın sayısı
Fernini, İ.	4
Manousakis, A.	4
El Naimiy, H.	2
El-Uveys, A.	2
Alamad, R.	2
El-Hâram, A.	2
Alhalife, M.	2
Alowais, A.	2
Elkasab, Y.	2
Balogh, W.	2

En üretken ülkelere ait bilgiler Tablo 3'te verilmiştir. En üretken ülke 18 yayınla Amerika Birleşik Devletleri (ABD) olmuştur. ABD uzay biliminde YZ kullanımı üzerine yayın üretmede lider konumdadır. ABD'yi Çin, Hindistan ve Birleşik Arap Emirlikleri takip etmektedir.

Tablo 3. En üretken ülkeler

Ülke	**Yayın Sayısı**
Amerika Birleşik Devletleri	18
Çin	9
Hindistan	7
Birleşik Arap Emirlikleri	5
Avustralya	4
İtalya	4
Avusturya	3
Bahreyn	2
Belçika	2
Hollanda	2
Romanya	2
Güney Kore	2
İsveç	2
İsviçre	2
Birleşik Krallık	2
Bangladeş	1

En üretken kurumlara ait bilgiler Tablo 4'te verilmiştir. En çok yayın yapan iki kurumdan biri Çin Bilimleri Akademisi diğeri ise Birleşik Arap Emirlikleri'ne ait olan Sharjah Üniversitesi olup her iki kurumda 5 yayın sayısına sahiptirler.

Tablo 4. En üretken kurumlar

Kurum	Yayın sayısı
Çin Bilimler Akademisi	5
Sharjah Üniversitesi	5
Sharjah Astronomi, Uzay Bilimleri ve Teknoloji Akademisi	5
Uzay Kullanımı Teknolojisi ve Mühendislik Merkezi	4
NASA Goddard Uzay Uçuş Merkezi	3
LIQUIFER Sistemleri Grubu	2
NASA Ames Araştırma Merkezi	2
Röntgen Enstitüsü	2
Jet Tahrik Laboratuvarı	2
Ulusal Havacılık ve Uzay Dairesi	2

Tablo 5'te yayınların toplam atıf sayılarını göstermektedir. Uzay bilimi ve YZ'nin ilişkilendirildiği yayınlar 868 toplam atıf sayısı almıştır. 2021 yılında Yu, S. ve Ma, J. tarafından yayınlanan "Deep Learning for Geophysics: Current and Future Trends" 344 atıf alarak en yüksek toplam atıf sahip yayın olmuştur. Ardından 83 toplam atıf sayısına sahip "Improvement of a Deep Learning Algorithm for Total Electron Content Maps: Image Completion" yayın gelmektedir.

Tablo 5. Yayın toplam atıf sayıları

Belge başlığı	Yazarlar	Yıl	Atıf
Deep Learning for Geophysics: Current and Future Trends	Yu, S., Ma, J.	2021	344
Improvement of a Deep Learning Algorithm for Total Electron Content Maps: Image Completion	Chen, Z., Jin, M., Deng, Y., (...), Deng, X., Huang, C.-M.	2019	83
Mapping potential landfill sites for North Sinai cities using spatial multicriteria evaluation	Effat, H.A., Hegazy, M.N.	2012	76
What makes you tick? The psychology of social media engagement in space science communication	Hwong, Y.-L., Oliver, C., Van Kranendonk, M., Sammut, C., Seroussi, Y.	2017	75
ON THE FUTURE: PROSPECTS FOR HUMANITY (Book)	Rees, M.	2021	67
Review on advanced health monitoring methods for aero gas turbines using model based methods and artificial intelligent methods	Kong, C.	2014	37
Space development and space science together, an historic opportunity	Metzger, P.T.	2016	35
SAIRE - a scalable agent-based information retrieval engine Open Access	Odubiyi, Jide B., Kocur, David J., Weinstein, Stuart M., (...), Gokey, Chris, Graham, JoAna	1997	21
Supervised Classification for Analysis and Detection of Potentially Hazardous Asteroid	Bahel, V., Bhongade, P., Sharma, J., Shukla, S., Gaikwad, M.	2021	16

Tablo 6'da yayınlarda en sık kullanılan kelimeler gösterilmiştir. En sık kullanılan kelimelere ait kelime bulutu Şekil 2'de gösterilmiştir. En sık kullanılan kelime "artificial ıntelligence" olmuştur. Şekilde en büyük ve merkezi konumda yer alan "artificial intelligence" ifadesi, yapay zekânın bu alandaki araştırmaların odak noktasını oluşturduğunu göstermektedir. Ardından "space science" ve "space research" kelimeleri gelmektedir. Ayrıca "machine learning", "deep learning", "remote sensing", "decision support systems" ve "engineering education" gibi ifadelerin de sıkça tekrarlandığı görülmektedir. Bu durum, YZ'nin yalnızca veri analizi ve sistem optimizasyonu gibi teknik alanlarda değil, aynı zamanda mühendislik eğitimi ve karar destek sistemleri gibi daha geniş kapsamlı uygulamalarda da etkin biçimde kullanıldığını ortaya koymaktadır.

Tablo 6. En sık kullanılan kelimeler

Kelime	Tekrar edilme sayısı
artificial intelligence	32
space science	13
space research	12
students	9
space technologies	7
decision making	6
earth (planet)	6
engineering education	6
machine-learning	5
remote sensing	5



Şekil 2. En sık kullanılan kelimelere ait kelime bulutu

Sonuç ve Öneriler

Son yıllarda YZ teknolojilerindeki gelişmeler, bu teknolojilerin uzay bilimi çalışmalarında giderek daha yaygın şekilde kullanılmasını sağlamıştır. Bu çalışma, uzay biliminde YZ kullanımı üzerine mevcut literatürün bibliyometrik analiz yöntemiyle incelenerek alandaki araştırma eğilimlerini, önde gelen aktörleri ve tematik gelişimini ortaya koymayı amaçlamıştır. 1987-2025 yılları arasında Scopus veri tabanından elde edilen verilerin analizinde, uzay biliminde YZ kullanımının son yıllarda artış gösterdiği görülmektedir. Uzay bilimlerinde YZ kullanımı ile ilgili yayınların 2020 sonrasında belirgin bir artış gösterdiği tespit edilmiştir. Bu artış YZ teknolojilerinin gelişimiyle paralellik göstermektedir. Yayınlanan 67 yayında İngilizce, 3 yayında ise Çince dili kullanılmıştır. En fazla yayın üreten ülkeler sırasıyla ABD, Çin, Hindistan, Birleşik Arap Emirlikleri gelmektedir. Yayın üretiminde ülkelerin başarısında, devlet politikaları, finansal yatırımlar, yetişmiş insan gücü ve uluslararası iş birlikleri gibi faktörler etkili olmaktadır. ABD'nin güçlü araştırma merkezlerine sahip olması, uzay şirketlerine yapılan yüksek bütçeli yatırımlar ülkenin lider konumda olmasında etkili faktörlerdir. Kurumların yayın üretiminde Çin Bilimleri Akademisi, Sharjah Üniversitesi ve Sharjah Astronomi, Uzay Bilimleri ve Teknolojisi Akademisi en fazla yayın üreten kurumlar olmuştur. Fernini ve Manousakis uzay biliminde YZ kullanımı üzerine en fazla yayın üreten yazarlar olarak alanda öne çıkmaktadır. 2021 yılında Yu, S., Ma, J.tarafından yayınlanan "Deep Learning for Geophysics: Current and Future Trends" yayını 344 atıf alarak en fazla atıf alan yayın olmuştur. Yayınlarda en fazla tekrar eden kelimeler "artificial ıntelligence", "space science" olmuştur. Bu kelimeler YZ'nin uzay biliminde merkezi rolü olduğunu doğrulamaktadır. Çalışmada bulgular Scopus veri tabanı kullanılarak elde edilmiştir. Biblioshiny ve Scopus veri analizi ile bibliyometrik analiz yapılmıştır. İleride yapılacak araştırmalarda yalnızca Scopus veri tabanı değil, Google Scholar, Web Of Science gibi veri tabanları da kullanılabilir. Çeşitli veri tabanlarının kullanılması ileride yapılacak araştırmalar için destekleyici olacaktır.

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INTRUSION DETECTION FOR IOT DEVICES USING FEDERATED LEARNING

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ABSTRACT

With the widespread use of network access, the security threats to devices and data within the network have significantly increased. Machine learning models have demonstrated high performance and accuracy in Intrusion Detection Systems for attack detection. However, the centralized structure of classical machine learning models cannot ensure the security of sensitive user data. Federated Learning has emerged as an approach that allows model training by keeping all data confidential instead of using centralized data. With Federated Learning, model training is performed on client devices where user data is generated. After training, the model weights from each client are transmitted to a central server, where they are aggregated to update and improve the global model. In this study, we used the CICIoT2023 dataset, which contains both benign data and seven types of attack data: DDoS, DoS, Recon, Web-Based, Brute Force, Spoofing, and Mirai collected from a range of IoT devices. All attack types were labeled as “Malicious,” resulting in a binary-classified dataset. The dataset was then equally divided into ten parts, with each part assigned to a separate client. Each client trained an Artificial Neural Network model on its respective subset to distinguish between benign and malicious traffic. The model weights from each client were transmitted to a central server using Federated Learning. According to the results, the loss value obtained as 4,91% and the accuracy was 98.87%. These results demonstrate that Federated Learning effectively enhances the classification of malicious and benign traffic, enabling IoT devices to collaboratively improve cybersecurity without compromising user data privacy.

Keywords: Network Security, Federated Learning, Machine Learning, Attack Detection

Introduction

Federated learning is an emerging machine learning approach that enables collaborative model training across multiple devices while keeping data decentralized and private. Federated learning can ensure privacy preservation and protection of sensitive information (Pandya et al., 2023). Privacy is preserved by transmitting only model updates instead of raw data to a central server with this approach. This distributed approach adapts to the dynamic nature of IoT networks, improving model accuracy over time.

This research aims to address security concerns in IoT devices by considering user data privacy with the FL approach ANN model using the CICIoT23 dataset. Contribution of the study is classify network attempts whether they are benign or malicious using decentralized data approach with recent dataset CICIoT23.

Related Works

This section discusses FL studies in the field of network security conducted in 2023-2024.

In (Al-Wesabi et al., 2023), presented in which a model combining the Pelican Optimization algorithm with Federated Learning is proposed to detect cyber-attacks in IoT environments. The findings show that the proposed model achieves higher accuracy of 99.41% compared to traditional methods. A two-level privacy preserving framework is presented in a study (Rabieinejad et al., 2024) that combines federation learning with partially homomorphic encryption. According to the results of the study, the proposed framework significantly improves attack prediction error rates and reduces false alarms compared to traditional methods. The study in (Thein et al., 2024) explores a federated learning-based Intrusion Detection System (IDS) for IoT data, focusing on two main challenges: data heterogeneity and poisoning attacks from malicious clients. It is proposed in the study a method called pFL-IDS. This approach effectively detects poisoning attacks without reducing performance compared to baseline methods. The study in (M. M. Salim et al., 2024) presents a novel Cyber Threat Detection System for IoT networks using Digital Twin technology combined with an optimized Federated Learning approach. It employs an Adaptive Thresholding with Early Stopping method to enhance local model training and integration, improving accuracy and efficiency. Compared to traditional federated averaging, the system shows superior performance with higher F1 scores and lower CPU usage, demonstrating the potential of this approach for securing IoT networks. In (Lai et al., 2023) it is proposed a two-stage defense mechanism called Defense of Poisoning Attacks in Federated Learning (DPA-FL) for intrusion detection. In the first stage, it compares the relative differences in model weights to identify discrepancies between benign and malicious participants. The second stage tests the collected model with the dataset and tries to find the attackers when its accuracy is low. The results of the study achieving up to 96.5% defense accuracy. In a study (Yang et al., 2023) where a detection mechanism is proposed to reduce the impact of poisoning attacks against FL-based intrusion detection methods in IoT networks, experimental results indicate that the proposed detection method can provide defense against label flipping attacks in FL. In (Doriguzzi-Corin & Siracusa, 2024), FLAD (Adaptive Federated Learning Approach to DDoS Attack Detection), an adaptive mechanism-based FL solution for cybersecurity applications, was proposed. A recent DDoS attacks dataset was used in the study, and according to the findings, FLAD outperformed the latest FL algorithms in terms of convergence time and accuracy among imbalanced datasets of heterogeneous DDoS attacks. In (Liu et al., 2023), an asynchronous federated learning arbitration framework based on Bi-directional LSTM (bi-LSTM) and attention mechanism (AsyncFL-bLAM) is proposed. According to the results of the study, it is stated that AsyncFL-bLAM outperforms the state-of-the-art models in terms of accuracy and reduces the overall communication rounds. In (Tran et

al., 2023), a cross-silo federated learning scheme with privacy protection is proposed. The proposed scheme is theoretically and experimentally demonstrated to provide provable privacy against an honest but curious aggregator server and simultaneously obtain the desired model utilities. The scheme is applied to false data injection attack detection (FDIA) in smart grids. The study states that the proposed scheme is a cross-silo FDIA federated learning that is more secure than existing works and resistant to local private data inference attacks. In (S. Salim et al., 2024), a deep federated learning (DFL) based threat detection model is proposed, incorporating a decentralized data-level preprocessing (DLP) mechanism to maintain data confidentiality while enabling effective threat detection. The model uses a deep autoencoder architecture, performing federated learning rounds by sharing only learned weights. Experimental results show that this approach outperforms traditional centralized models in both data privacy and attack detection accuracy. In (Jithish et al., 2023) where a smart grid anomaly detection scheme based on Federated Learning (FL) was proposed, a global model was downloaded from the server to smart meters for on-device training. After local training, local model parameters were sent to the server to improve the global model. Model parameter updates were protected from attackers using the SSL/TLS protocol. According to the findings, FL models achieved similar anomaly detection performance to centralized ML models while ensuring user privacy. In (Wang et al., 2024), a Free-Rider Attack Detection (FRAD) mechanism for federated learning is proposed using a Deep Autoencoding Gaussian Mixture Model (DAGMM) based on contribution and reputation. the contribution values of each device node based on computational resource, communication cost and data quality are modeled and applies a PageRank-based reputation model to select reliable participants. Simulation results show that FRAD outperforms existing methods in defending against free-rider attacks. A defense mechanism attestedFL, which monitors the training of individual nodes via state persistence to detect a malicious worker in small to medium-sized federations, has been proposed in a study(Mallah et al., 2023).The study presents a defense framework with three lines of defense to assess the trustworthiness of worker nodes by monitoring their training behavior and progress. It effectively identifies and excludes malicious or untrustworthy nodes, accelerating federated learning convergence. Results show that AttestedFL improves model accuracy under various attack scenarios, including early-stage attacks, collaborating attackers, and continuous attacks. Table 1 presents the related research carried out in 2023 and 2024 using various datasets and methods.

Table 2. FL studies in the field of network security conducted in 2023-2024

Authors	Method	Dataset	Performance
Al-Wesabi et al.	DBN, Pelican Optimization Algorithm with FL - (POAFL-DDC)	TON_IOT	99,19% accuracy
Rabieinejad et al.	FL, Partially Homomorphic Encryption, FedAvg	UNSWNB15 and Bot-IoT	UNSWNB15:92,13% Accuracy- Bot-IoT:98,97 % Accuracy
Thein et al.	FL, FedAvg, CNN - pFL-IDS	N-BaIoT	Higher accuracy than 98,80%
M. M. Salim et al.	Digital Twin and FL- DTFL-CD, ANN	CICDDoS 2019	F1-Score: 82%
Lai et al.	Reinforcement learning, Local Outlier Factor	CICIDS2017	96.5 % Accuracy
Yang et al.	FL	CIC-IDS-2017	97.1 % Accuracy
Doriguzzi-Corin & Siracusa	FLAD (Adaptive FL Approach to DDoS Attack Detection) FedAvg	CICDDoS2019	92,32 % Accuracy
Liu et al.	Bi-directional LSTM and attention mechanism (AsyncFL-bLAM)	LDDoS	98.68% Accuracy
Tran et al.	Cross-silo federated learning scheme	SimBench, PowerFactory, 2017 SP4	97,88% F1-Score
S. Salim et al.	Deep federated learning (DFL) based threat detection model, Deep Auto-Encoder (DAE), FL.	Local Dataset	97% Accuracy
Jithish et al.	FL based smart grid anomaly detection, Tensorflow Federated Framework, ML Methods	DD 99, NSL-KDD,CIDDS-001	95,3% Accuracy
Wang et al.	FRAD: Free-Rider Attacks Detection Mechanism, Deep Autoencoding Gaussian Mixture Model	MNIST, CIFAR-10	~83% accuracy with 80% Free-Rider ratio
Mallah et al.	attestedFL	Local dataset, MNIST, CIFAR-10, MTL, Trajet	90% Accuracy

Recent studies show that by integrating techniques such as optimization algorithms, encryption, adaptive mechanisms and deep learning, FL-based approaches improve attack detection accuracy. Several defense frameworks have been proposed to protect against adversarial behaviors while maintaining privacy and model performance.

Material and Methodology

In this study, a collaborative federated learning study was conducted with an ANN model by sharing and distributing the CICIoT23 dataset (Neto et al., 2023) to 10 numbers of clients.

Material

In this study CICIoT23 dataset (Neto et al., 2023) was utilized. This dataset was generated by executing 33 distinct attacks on an IoT network topology comprising 105 devices, with the aim of creating a comprehensive resource to support the development of security solutions for IoT environments. The attacks are categorized into seven main groups: DDoS, DoS, Reconnaissance, Web-based, Brute Force, Spoofing, and Mirai. Notably, all attacks were

initiated by compromised IoT devices targeting other IoT devices within the network. Details regarding the dataset preprocessing are provided in the following section.

Data preprocessing

The attacks in the dataset, which fall into seven distinct categories, were all labeled as malicious, thereby converting the dataset into a binary classification format with two classes: benign and malicious. However, a significant class imbalance was observed between the number of benign and malicious samples. To address this, the dataset was first divided into 10 equal partitions to be distributed among the clients. Subsequently, an undersampling technique—commonly used for handling class imbalance—was applied to each partition individually. Figure 1 illustrates the distribution of class labels before applying undersampling and partitioning the dataset among clients. Figure 2 presents the balanced class label distribution for a sample client after preprocessing. The complete data preprocessing workflow is visualized in Figure 3.

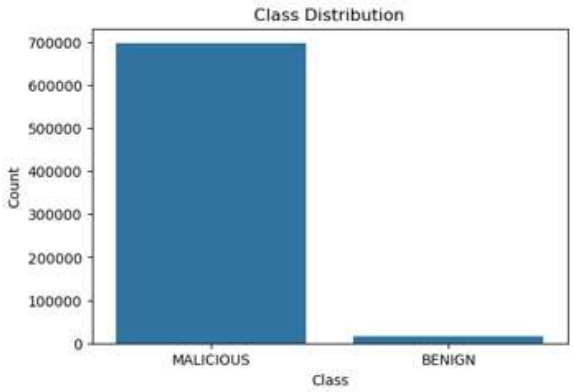


Figure 1. Number of labels before splitting the dataset into equal parts and undersampling

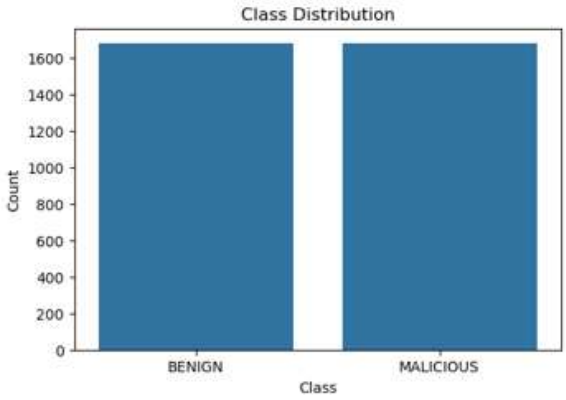


Figure 2. Sample seperated dataset after undersampling process

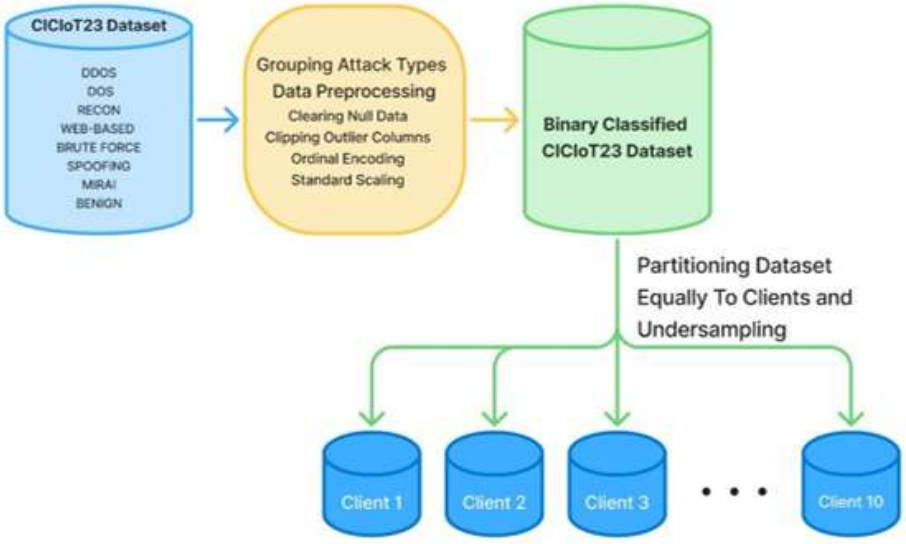


Figure 3. Data Preprocessing Steps

Methodology

Artificial Neural Network (ANN)

The Artificial Neural Network (ANN) is a mathematical model designed to emulate the structure and functionality of biological neural networks. The fundamental building block of an ANN is the artificial neuron—a mathematical function that simulates the behavior of a biological neuron (Krenker et al., 2011). The general form of the artificial neural network is expressed in Equation (1).

$$\gamma = \begin{cases} 1, & If \sum_{i=1}^{n} \theta_i . \times_i \geq \tau \\ 0, & If \sum_{i=1}^{n} \theta_i . \times_i < \tau \end{cases} \qquad (1)$$

γ: Neuron output value

x_i: *Input signal*

θ_2: *Weight*

τ: *Threshold*

In this study, an Artificial Neural Network (ANN) model was employed within a Federated Learning framework. The ANN architecture consists of two hidden layers comprising 128 and 64 neurons, respectively, followed by an output layer with a sigmoid activation function.

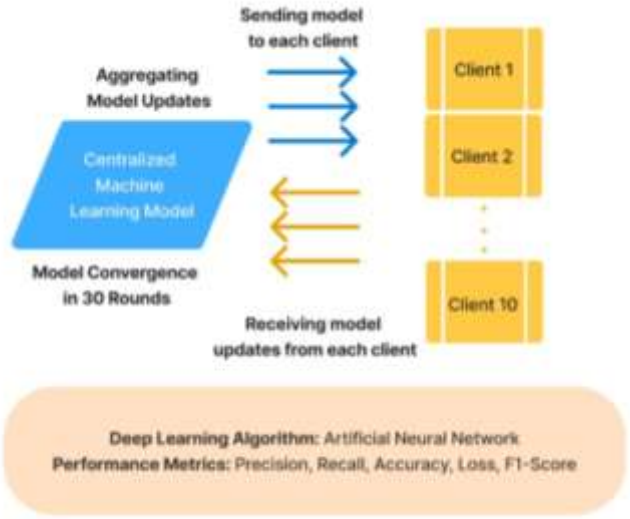
Federated Learning

Devices such as smartphones and tablets are now widely used and are equipped with various sensors, including cameras, microphones, and GPS, which can access vast amounts of data—much of it highly sensitive. The private nature of this data introduces significant risks and ethical concerns when stored in centralized locations. Federated Learning offers a privacy-preserving machine learning paradigm that mitigates these risks by eliminating the need to collect raw data centrally. Instead, each participating device independently trains a model using its local data and transmits only the model updates to a central server, ensuring data remains on the device (McMahan et al., 2017).

Proposed Model

In this study, the CICIOT23 dataset was employed to train an artificial neural network model using the Federated Learning approach. The FedAvg algorithm was implemented through the Flower (FLWR) framework. Evaluation metrics such as Accuracy, Precision, Recall, and F1-score were computed using a weighted average based on the data sizes of the participating clients. In the FedAvg process, the model is trained locally on each client device using its own data. After local training, each client transmits its updated model weights to a central server, which aggregates them using a weighted average to construct a new global model. The architecture of the proposed model is illustrated in Figure 4.

Figure 19. Visualization of Proposed Model



Experimental Results

During each training round, the model weights are updated by averaging the weights received from all participating clients. The updated global model is then distributed back to the clients. According to the results obtained after the 30th round, the model achieved an Accuracy of 98.87%, an F1-Score of 98.87%, a Recall of 98.87%, a Precision of 98.90%, and a Loss value of 4.91%.

Following all training rounds, the confusion matrix of the final global model (Figure 5) indicates that all malicious attacks were correctly classified. However, the model incorrectly classified 78 benign instances as malicious. The detailed performance of the model across each training round is presented in Table 2.

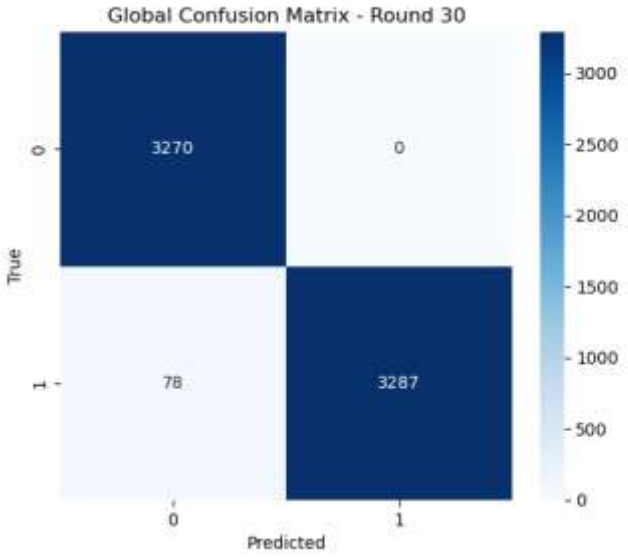


Figure 20. Confusion matrix of the current global model at the end of all rounds.

Table 3. Performance of global model during each round

Round	Loss	Accuracy	F1 Score	Precision	Recall
1	10,28	98,52	98,52	98,56	98,52
2	8,30	98,69	98,69	98,72	98,69
3	7,56	98,70	98,70	98,74	98,70
4	7,18	98,72	98,72	98,75	98,72
5	6,38	98,75	98,75	98,78	98,75
6	6,03	98,76	98,76	98,80	98,76
7	5,97	98,78	98,78	98,81	98,78
8	5,57	98,78	98,78	98,81	98,78
9	5,58	98,78	98,78	98,81	98,78
10	5,51	98,75	98,75	98,78	98,75
11	5,16	98,78	98,78	98,81	98,78
12	5,15	98,79	98,79	98,83	98,79
13	5,24	98,78	98,78	98,81	98,78
14	5,04	98,84	98,84	98,87	98,84
15	5,05	98,82	98,82	98,85	98,82
16	5,07	98,81	98,81	98,84	98,81
17	5,04	98,82	98,82	98,85	98,82
18	5,04	98,81	98,81	98,84	98,81
19	5,04	98,81	98,81	98,84	98,81
20	5,02	98,82	98,82	98,85	98,82
21	5,00	98,82	98,82	98,85	98,82
22	4,98	98,84	98,84	98,87	98,84
23	4,98	98,85	98,85	98,88	98,85
24	5,08	98,82	98,82	98,85	98,82
25	5,00	98,85	98,85	98,88	98,85
26	4,96	98,85	98,85	98,88	98,85
27	4,92	98,85	98,85	98,88	98,85
28	4,94	98,85	98,85	98,88	98,85
29	4,93	98,87	98,87	98,90	98,87
30	4,91	98,87	98,87	98,90	98,87

According to Table 2, the model was effectively trained on each client throughout all rounds. The final global model demonstrated high performance, achieving an accuracy of 98.87%.

Conclusion and Recommendations

Federated Learning is a promising approach that enhances the efficiency of machine learning models while preserving user privacy. By enabling sensitive data to remain on the devices where it is generated, Federated Learning eliminates the need to transfer such data to a central server, thereby supporting the development of effective and privacy-aware intelligent systems. In this study, a Federated Learning environment was implemented using the CICIoT23 dataset. An artificial neural network model was trained locally on client devices, without transferring raw data to the central server. Instead, only model weights were aggregated on the server to construct the final global model. The experimental results demonstrate that the Federated Learning approach can achieve high performance—particularly in the context of cybersecurity for IoT devices, which are increasingly prevalent and inherently vulnerable to security threats.

For future work, it is recommended to explore Federated Learning in multi-class classification scenarios involving clients with non-uniform data distributions. Additionally, integrating various optimization techniques and comparing their impacts on model convergence and performance could further enhance the robustness and applicability of Federated Learning in real-world IoT environments.

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INVESTIGATION OF BEAM COMPENSATIONON DIMENSIONAL ACCURACY OF A LPBF-MANUFACTURED Co–Cr ALLOY JET ENGINE COMPONENT

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ABSTRACT

Additive manufacturing via laser powder bed fusion (LPBF) has revolutionized the production of complex metal parts by enabling high geometric freedom and near-net-shape fabrication. Cobalt-chromium (Co-Cr) alloys, prized in aerospace for their exceptional high-temperature strength, oxidation and corrosion resistance, are increasingly adopted for LPBF fabrication of jet engine components. Although numerous LPBF parameters—such as laser power, scan speed, hatch speed, and layer thickness—can influence dimensional accuracy, beam compensation (BC) has substantial effect on the dimensions of the produced parts. This parameter defines an offset between the original slice contour and the outermost boundary to ensure the part is built to the correct dimensions. In this study, five identical Co–Cr jet engine components were printed under constant LPBF settings with only the BC value systematically varied (45-105 µm) between builds. Each as-built component was measured using a high-precision coordinate measuring machine (CMM) to quantify deviations from the nominal CAD geometry in critical features. Results show that the optimal BC setting yielded dimensional deviations of less than 1% on the inner diameter and under 0.6 % on the outer diameters, demonstrating high accuracy to the nominal design. These findings underscore the significant role of BC in achieving near-net-shape accuracy of LPBF-fabricated parts and provide practical guidelines for selecting compensation values that minimize post-process work.

Keywords: Additive manufacturing, laser powder bed fusion, Co-Cr alloys, dimensional accuracy

Introduction

In recent years, additive manufacturing (AM) technologies have gained significant attention for their ability to produce complex, lightweight, and high-performance components. Among these techniques, Laser Powder Bed Fusion (LPBF) has emerged as one of the most advanced methods, offering the capability to fabricate intricate metallic structures with excellent precision. In the LPBF process, a high-power laser selectively melts layers of metal powder based on a digital CAD model. After each laser scan, a fresh layer of powder is recoated, and this layer-by-layer approach continues until the entire part is fabricated. The LPBF process provides notable advantages, such as design flexibility, material efficiency, and the potential to reduce component mass—attributes that are critical in advanced engineering applications. (Yildiz & Babacan, 2024) (Aktürk et al., 2025)

Cobalt–Chromium–Molybdenum (Co–Cr–Mo) alloys are widely utilized in LPBF due to their exceptional high-temperature strength, superior wear and corrosion resistance, and excellent biocompatibility. These properties make Co–Cr–Mo alloys highly suitable for demanding applications in sectors such as aerospace, biomedical, and energy. The growing demand for lightweight and complex components has further driven interest in processing Co–Cr–Mo alloys through advanced AM techniques. (Acharya et al., 2021).

To ensure reliable processability in LPBF, Co–Cr–Mo alloy powders are typically produced via Vacuum Inert Gas Atomization (VIGA). This technique enables the production of powders with highly spherical morphology, uniform particle size distribution, and good chemical homogeneity — all of which are critical for maintaining stable powder flow and achieving consistent melting behavior during the LPBF process.

However, the mechanical properties, microstructure, and dimensional accuracy of LPBF-fabricated parts are affected by numerous LPBF process parameters, such as laser power, scanning speed, hatch distance, layer thickness, and scanning strategy. Among these factors, dimensional accuracy is particularly influenced by the offset between the laser scan path and the boundaries of the intended part geometry, which is governed by the melt pool geometry (Fig. 1a). This offset is controlled through the beam compensation (BC) (Fig. 1b), which helps to minimize dimensional deviations and improve the accuracy of the final part.

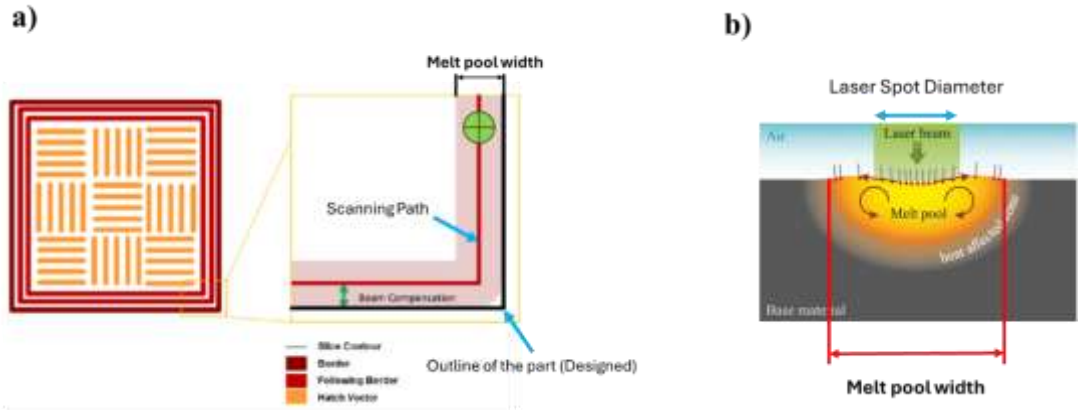


Figure 1. (a) Illustration of the BC; (b) Illustration of the melt pool boundary.

In this study, the effect of different BC settings on the dimensional accuracy of an aerospace jet engine component produced by LPBF from Co–Cr–Mo alloy powder was investigated. The findings aim to support the optimization of LPBF parameters for precision manufacturing of critical components in high-performance applications.

Materials and Methods

Co–Cr–Mo alloy powder with a spherical morphology was produced in-house via VIGA in compliance with the ASTM F75 standard. The powder was subsequently sieved to obtain a particle size range of 10–53 µm.

Five different jet engine components were fabricated using the LPBF (Ermaksan, EnaVision 130) process, employing 5 different BC parameters (45, 60, 75, 90, and 105 µm) under a nitrogen atmosphere. The following optimized process parameters were used during the production: laser power (180 W), scanning speed (581 mm/s), hatch distance (88 µm), layer thickness (30 µm), and laser spot diameter (75 µm). These parameters were chosen based on previous studies (Yıldız et al., 2023; Yıldız et al., 2025). A heat treatment was conducted at 750 °C for 2 hours to relieve internal stress and obtain suitable microstructure within the fabricated parts.

A Coordinate Measuring Machine (CMM) was used to measure five different diameters on each part, as the measurement locations illustrated in Fig. 2. Fig. 3 shows the setup and the CMM during the measurement process. After the measurements, the results were compared with the designed dimensions in terms of percentage deviation.



Figure 2. Measurement locations on the part surfaces (green-colored surfaces).

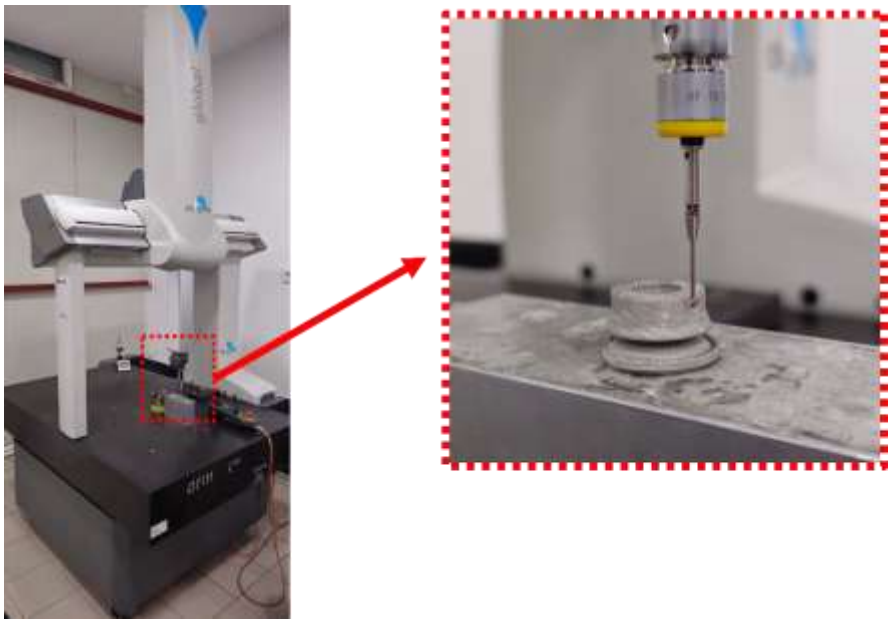


Figure 3. Images of the measurement process using a CMM.

Findings and Discussion

Table 1 presents the relative dimensional deviations between the designed model and the manufactured parts. For practical applications, inner diameters must be produced with negative tolerance, while outer diameters require positive tolerance. Consequently, the fourth and fifth parameter sets are unsuitable for production, as their dimensions fall below the design specifications. In contrast, the first three parameter sets are acceptable for production. In particular, the third parameter set—with a 75 µm BC—produced dimensions very close to the design. This minimizes post-processing effort and reduces overall processing time.

Table 1. Relative dimensional deviation between the designed model and the produced part

Sample	Beam Compensation (BC) (µm)	ID-1 (%)	OD-1 (%)	OD-2 (%)	OD-3 (%)	OD-4 (%)
1	45	-2.34	0.29	0.73	0.45	0.54
2	60	-1.98	0.13	0.43	0.10	0.27
3	75	-0.99	0.33	0.53	0.24	0.28
4	90	0.48	0.01	0.40	0.03	0.34
5	105	0.59	-0.54	-0.01	-0.26	-0.25

*ID: inner diameter, OD: outer diameter

Figure 4 illustrates the influence of BC on part geometry near the borders. When the BC value is low, the laser scan path lies too close to the nominal contour. Due to the outward spread of the melt pool, the effective melting does not fully reach the intended boundary, resulting in undersized dimensions. Conversely, if the BC value is too high, the scan path shifts excessively outward, causing the melt pool to extend beyond the nominal boundary and resulting in oversized dimensions. Thus, dimensional accuracy strongly depends on the alignment between the BC value and the actual melt pool width. In this study, the optimal dimensional accuracy was achieved with a BC value of 75 µm, which closely corresponds to the measured melt pool width. This correlation will be examined in greater detail in future investigations.

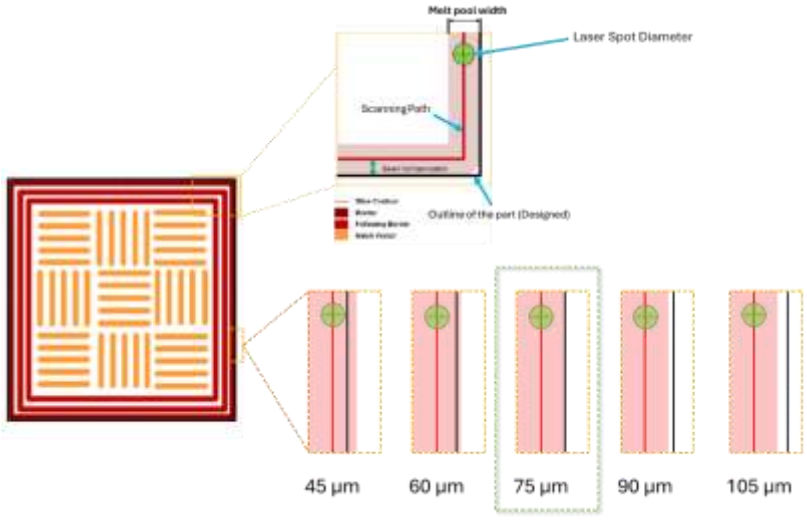


Figure 4. Schematic illustration of the effect of the BC parameter

Conclusion

In this study, the effect of beam compensation (BC) parameters on dimensional accuracy of LPBF-produced part is investigated and following conclusions are obtained:

- BC values significantly influence the dimensional accuracy of LPBF-manufactured components.
- Dimensional accuracy can be optimized solely by adjusting the BC parameter, without requiring any design modifications, provided that the process parameters have already been optimized.S
- Near-net shape parts can be successfully fabricated through LPBF, highlighting the process's potential for precise and efficient production.

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HEALTH BEHAVIOR CHANGE IN NURSING PRACTICE: TRANSTHEORETIC MODEL APPROACH

HEMŞİRELİK UYGULAMALARINDA SAĞLIK DAVRANIŞI DEĞİŞİMİ: TRANSTEORETİK MODEL YAKLAŞIMI

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ABSTRACT

The Transtheoretical Model (TTM) was developed by James Prochaska and Carlo DiClemente to explain the health-related behaviour change processes of individuals. This model offers a gradual approach by taking into account the readiness levels of individuals for behaviour change and differs from traditional 'all or nothing' based approaches in this respect. TTM is used effectively in many areas such as smoking cessation, starting physical activity and healthy nutrition. In this paper, the basic structure of the model, its effects on health behaviours and its application examples in nursing are discussed.

The model consists of five stages: 'not thinking, thinking, preparation, action and maintenance'. Intervention strategies are planned according to the attitudes and needs of the individual at each stage. The cognitive and behavioural processes offered by TTM are structured with variables such as increasing the individual's awareness, providing environmental regulations, activating social support systems and replacing unhealthy behaviours with healthy alternatives. In addition, the individual's self-efficacy level, incentive factors and decision-making mechanisms are also important components of the model.

When the literature is examined, it is seen that TTM is effective in the development of health behaviours at both individual and community level and is widely used in nursing practices, especially in areas such as smoking cessation, exercise, nutrition and health screenings. In this context, the model supports the counselling and training roles of nurses and provides a scientific basis for individual-specific, stage-based health promotion interventions.

Keywords: Transtheoretical Model, Behavior Change Stages, Health Promotion, Motivational Interviewing

1. Transteoretik Model

Transteoretik Model **(**TTM), 1982 yılında psikolog James Prochaska ve Carlo Diclemente tarafından geliştirilmiştir (Di Noia ve Prochaska, 2010; Prochaska, 1982). Son yıllarda pek çok hastalığın önlenmesi ve tedavisi için öncelikle sağlıksız davranışların değiştirilmesi gerektiğinin farkına varılmıştır (Bulduk ve ark., 2015). TTM'in kullanıldığı alanlar; sigarayı bırakma, egzersiz yapma, güneşten korunma, kanser, tip 2 diyabet, AIDS, osteoporoz, anoreksiya nevroza, prezervatif kullanımı, mamografi taraması, ilaç kullanımı, stres, madde bağımlılığını ve sağlıklı beslenme şeklinde sıralanmaktadır (Başakçı, 2019). Ayrıca model pek çok sağlıksız davranışa da uyarlanabilmektedir. Modele göre birey sağlıksız davranışını fark ettiği an davranış değişim süreci başlar ve sağlıklı davranışı kazanana kadar bu süreç devam eder. Sağlık davranış değişimi ile ilgili yapılan çalışmalarda TTM, Sosyal Bilişsel Teori, Planlı Davranış Teorisi, Sağlık İnanç Modeli gibi teori ve modeller kullanılmaktadır (Davies ve ark., 2010; Li ve ark., 2015; Plotnikof ve ark., 2013; Webb ve ark., 2010). Sağlık davranış modelleri içerisinde en yaygın olarak kullanılanı TTM'dir ve sağlık davranışı ile ilgili birçok alanda kolayca uygulanabilir (Dray ve Wade, 2012; Glanz ve ark., 2008; Jackson, 2007; Johonson ve ark., 2008). "Bu model diğer modellere göre neden önemli?" sorusu akla gelebilir. TTM'nin Sosyal Bilişsel Teori, Planlı Davranış Teorisi, Sağlık İnanç Modeli gibi modeller ile arasındaki ana fark, diğer modeller ya hep ya hiç olgusunu kullanarak sadece davranışsal ölçütleri açıklamak için geliştirilmiştir. TTM'nin gücü ya hep ya hiç olgusundan ziyade, dinamik olarak davranış değişimini ele almasından kaynaklanmaktadır (Marshall ve Biddle, 2001). Bir başka ifadeyle TTM, davranış değişimi için bireyin bulunduğu aşamanın hedef ve yaklaşımlarını kullanma olanağı sağlamaktadır. Diğer teoriler bu anlamda bireyin gereksinimlerini karşılamaktan uzaktırlar (Prochaska ve Velicer, 1997).

TTM'de bireyin davranış değişimi aşamalar halinde devam etmektedir. Modelin yapısında bu aşamalar şu şekilde açıklanmıştır. Bunlar; "düşünmeme, düşünme, hazırlık, hareket ve devam ettirme" aşamalarıdır (Prochaska ve Velicer, 1997). Bu aşamalar, bireyin sağlıksız davranışıyla ilgili olarak bireyin tutum, niyet ve davranışlarını yansıtmaktadır. Modelde bireyin değişimi için gerekli olan şey yine bireyin isteğine ve motivasyonuna bağlı gelişmektedir. TTM'de davranış değişiminde bireylerin başarısı, davranışı gerçekleştirip gerçekleştirmediğinden çok, içinde olduğu aşamanın değişimine göre değerlendirilir (Tosun ve Zincir, 2015).

Transteoretik Model'in yapısı üç aşamalıdır.

1. Değişim Aşamaları (zamanla ilgili boyut)

2. Değişim Süreci (bağımsız değişken boyutu)

3. Öz-etkililik/Teşvik Eden Faktörler/ Karar Alma Ölçekleri (değişimin düzeyleri) (Erol ve Erdoğan, 2008).

1.1. Değişim Aşamaları

Transteoretik modele göre sağlıksız davranışını sağlıklı davranışla değiştirmeye çalışan ve istekli olan her birey "düşünmeme, düşünme, hazırlık, hareket, sürdürme" aşamalarından geçer. Her aşamanın özellikleri birbirinden farklıdır. Davranış değişiminin gerçekleştirilmesi sürecinde danışman, her aşamaya özgü çeşitli teknikler ve stratejiler kullanmaktadır. Her aşama, bireyin sağlıklı davranışı elde edebilmek için gerekli olan ilgi, niyet ve motivasyon düzeylerini temsil eder. Motivasyon yöntemleri ise bireyin bir aşamadan başka bir aşamaya geçebilmesi için önemlidir. Birey genellikle ileri aşamaya geçme eğilimindedir. Ancak zaman zaman geri aşamaya dönme (relaps) durumu da olabilir. Bu durumun önüne geçmek için bireyin içinde bulunduğu aşama iyi değerlendirilmelidir. Her aşamaya özgü, uygun planlama ve

uygulama yapılmalıdır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.1.1. Düşünmeme Aşaması

Bireyin gelecek altı ay içinde istenen davranışa yönelik değişme niyetinin bulunmadığı aşamadır. Bu aşamada olan birey zararlı davranışından habersiz olabilir, çok az farkında olabilir ya da farkında olup değişimi istemeyebilir. Birey geçmişte başarısız girişimlerde bulunmuş olabilir. Kişinin, engel algısı yüksektir ve pek çok engel öne sürebilir. Bu nedenle bu aşamadaki bireye daha çok farkındalığının arttırılması ve öne sürülen engellerin aşılmasına yönelik girişimler planlanmalıdır. Bu aşamadaki bireye harekete geçmesine yönelik girişimler uygulanırsa direnç gösterebilir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.1.2. Düşünme Aşaması

Bireyin gelecek altı ay içerisinde sağlıklı davranışa başlama kararı aldığı aşamadır. Bu aşamadaki birey davranışı değiştirdiğinde elde edeceği yararların farkına varmıştır. Davranışlarıyla ilgili bilgi edinmeye daha açıktırlar. Ancak değişimi başlatma konusunda motive edilmesi ve güvenlerinin artırılması gereklidir. Bu aşamadaki birey yıllarca bu aşamada kalabilmektedir. Aşamadaki bireyler sıklıkla davranışı değiştirmek için ağırdan alma gibi eylemlerde bulunabilir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.1.3. Hazırlık Aşaması

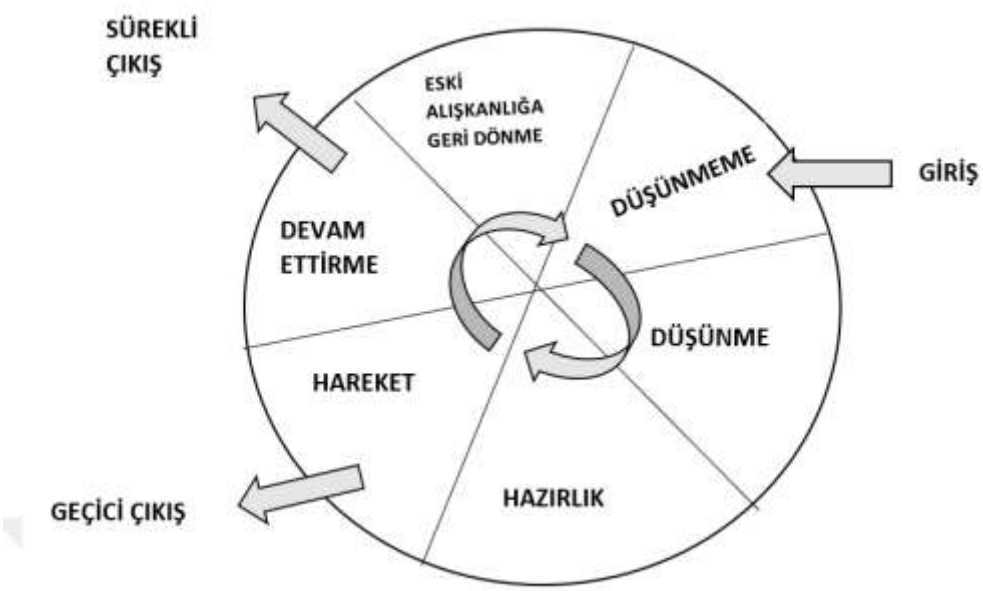
Bireyin yakın zamanda genellikle 30 gün içinde sağlıklı davranışa geçmeyi planladığı aşamadır. Bu aşamadaki birey genellikle davranışıyla ilgili sağlık eğitimine katılma, danışmanlık alma, davranışını değiştirmek için çeşitli kaynaklardan bilgi alma gibi planları vardır. Eylemleri düzenli ve etkin değildir. Aşamadaki bireye sağlıklı beslenme ve düzenli egzersiz için bir plan hazırlanmalıdır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.1.4. Hareket Aşaması

Bireyin edinmiş olduğu sağlıklı davranışı altı aydan kısa süredir uyguladığı aşamadır. Birey zamanını, enerjisini harcayarak sağlıklı davranışı edinmiş ve uygulamakta olduğu aşamadır. Bu aşama kritiktir ve bir önceki aşamaya dönme olasılığı vardır. Aşamadaki bireye sağlıklı beslenme ve düzenli fiziksel aktivite uygulama planı yeniden gözden geçirilmelidir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.1.5. Sürdürme Aşaması

Bireyin sağlıklı davranışı altı aydan uzun bir süredir yaptığı aşamadır. Sağlıklı davranışı devam ettireceği konusunda bireyin kendine olan güveni yüksektir. Bu aşamadaki bireye en önemli yaklaşım, stresle başa çıkma stratejilerinin öğretilmesidir. Bireyin geriye dönüşünü engellemek için çözüm (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).



Şekil 1: Prochaska ve Di Clemente'nin Değişim Aşamaları Spiral Modeli (Prochaska ve ark, 1992)

1.2. Değişim Süreçleri

Değişim süreci, davranış değişiminin gerçekleştirilmesi sürecinde bireye danışmanlık yapan kişilerin, sorunlu davranışı değiştirmek için kullandıkları bilişsel ve davranışsal strateji ve teknikleri içermektedir. Böylece değişim süreçleri, davranış değişim sürecinde danışmana rehber niteliği de taşımış olur. Değişim süreçleri; beş bilişsel ve beş davranışsal olmak üzere toplam on süreçten oluşmaktadır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.2.1. Bilişsel Süreçler

Bilinçlenme ya da farkındalığın artması: Bu süreçte birey sağlıksız davranışının neden olduğu sorunların farkına varmış, durumu kabullenmiş ve sağlıksız davranış hakkında yeni bilgi edinme ve geri bildirim verme çabası içerisine girmiştir.

Duygusal uyarılma: Bu süreçte birey sağlıksız davranışını başkası ile paylaşmakta ve kendisini duygusal 1olarak rahatlatmak istemektedir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Çevreyi yeniden değerlendirme: Bu süreçte birey sağlıksız davranışının fiziksel ve sosyal çevresini nasıl etkilediği üzerinde düşünmeye başlar ve kişisel alışkanlıkları ile çevresi arasındaki ilişkiyi bilişsel ve duygusal olarak değerlendirir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Kendini yeniden değerlendirme: Bu süreçte birey hayal gücünü kullanarak, rol model aldığı bireyleri düşünüp, kendini ve sağlıksız davranışını bilişsel ve duygusal açıdan değerlendirir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Sosyal özgürleşme ya da çevresel fırsatlar: Bu süreçte birey sağlıklı davranışı başlatma konusunda sosyal baskıdan uzaklaşmaya çalışır. Sosyal ve çevresel fırsatlar ve alternatiflerin farkına varır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

1.2.2. Davranışsal Süreçler

Karşıt durum ya da yerine koyma: Bu süreçte birey sağlıksız davranışının yerine koyacağı sağlıklı davranışını öğrenmeye odaklanır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Destekleyici ilişkiler: Bu süreç bireyi destekleyen, bireye güven veren ve kabul gören ilişkileri içerir. Birey kendine güven veren kişilerin desteğini kabul eder. Bu kişiler genellikle bireye birinci dereceden yakındır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Güçlendirme (ödüllendirme): Ödül, sağlıklı davranış edinmeye çalışan birey için motivasyon kaynağıdır. Bu nedenle birey sağlıklı sağlanışını sürdürdüğü zamanlarda kendine ödül verir ve daha fazla güçlenir (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Kendisi ile anlaşma: Bu süreç bireyin değişebileceğine olan inancını harekete geçirmesi ve uyum sağlamasıdır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).

Uyaranların kontrolü: Uyaran kontrolü, sağlıksız davranışa başlama riskini azaltmak ve daha sağlıklı alternatiflerle değiştirmek anlamına gelmektedir. Destek gruplarının oluşturulması ve gruba katılım, çevrenin düzenlenmesi gibi aktiviteler uyaran kontrolü içerisinde yer alır (Di Noia ve Prochaska, 2010; Menekli ve ark., 2019; Prochaska ve Di Clemente, 1982; Prochaska ve Velicer, 1997; Tosun ve Zincir, 2015).



Şekil 2. Değişim aşamaları ve değişim süreçleri eşleştirilmesi (Prochaska ve Velicer, 1997).

Birey, değişim aşamalarında ilerlerken, yaşadığı süreçleri belirten tablo yukarıdadır. Hangi değişim aşamasında, bireyin hangi süreçlerden geçtiğini bilmek, relapsı önlemek, zararlı baş etme yöntemlerinin geliştirilmesini önlemek ve patolojik tepkilerin farkına varılıp müdahale edilmesinin sağlanması gibi durumların tespitini kolaylaştırarak, bireyin davranış değişimini izlememize ve bireyin içinde bulunduğu aşama ve sürece özgü girişimlerde bulunmamıza olanak sağlar (Prochaska ve Velicer, 1997).

1.3. Değişim Seviyeleri

TTM, yapısında hassas değişimleri ölçebilen Öz Etkililik, Teşvik Eden Faktörler Ölçeği, Karar Alma Ölçeği gibi araçlar barındırır. Bu ölçeklerin diğerlerinden farkı, sadece sonucu değil, süreçteki ufak bilişsel, duygusal ve davranışsal değişimleri de hassas bir şekilde ölçebilmeleridir. Bu şekilde hemşirelik uygulamalarında, bireye özgü girişim planlamakta bizlere çok yardımları olmaktadır (Taş ve ark., 2016).

1.3.1. Öz-Etkililik

Öz-etkililik, insanların zorlayıcı durumlar karşısında problemli davranışa dönmeksizin, sağlıklı davranışı sürdürmede sahip olduğu güveni yansıtır (Koyun ve Eroğlu, 2016; Tosun ve Zincir, 2016).

Prochaska, Redding ve Evers (1997) öz etkililiği iki parçaya ayırmıştır (Koyun ve Eroğlu, 2016);

1. Kendine Güven: Bireyin belli bir davranışı başarı ile yapabileceğine ilişkin, kendisi hakkındaki inancıdır (Erol ve Erdoğan, 2007).

2. Teşvik Eden Faktörler: Bireylerin zorlayıcı durumlarla karşılaştıklarında eski alışkanlıklarına geri dönmelerini teşvik eden faktörlerin yoğunluğunu yansıtır (Erol ve Erdoğan, 2007).

Öz etkililik ölçeğinden alınan puanların yüksek olması, teşvik eden faktörlere rağmen baş edebilme gücünü ifade eder. Teşvik eden faktörler ölçeğinden yüksek puan alınması, eski davranışına yenik düşme ya da teşvik eden unsurlarının yüksek olduğunu gösterir (Erol ve Erdoğan, 2007).

1.3.2. Karar Alma

Janis ve Mann tarafından 1977'de geliştirilen Karar Alma; sağlıklı davranışın algılanan olumlu ve olumsuz yanlarının kıyaslandığı, aradaki dengenin ölçüldüğü basamaktır (Koyun ve Eroğlu, 2016; Tosun ve Zincir, 2016; Tümer ve ark., 2013). Karar alma ölçeği ise, davranış değişikliğinin yarar ve zarar algılarını ortaya koyar. Yarar, davranış değişiminin olumlu yönlerini, zarar ise davranış değişiminin olumsuz yönlerini yansıtır. Örneğin düşünmeme aşamasında, bireyin zarar algısı, her zaman yarar algısından daha ağır basar, düşünme aşamasına doğru ilerledikçe, yarar algısı artar (Erol ve Erdoğan, 2007; Koyun ve Eroğlu, 2016).

2. Transteoretik Model ve Hemşirelik

Hemşirelik mesleğinin doğası ve sorumlulukları arasında bireyin ve toplumun sağlığını koruma ve geliştirme yer almaktadır. Hemşireler bireyi bütüncül olarak değerlendiren ve tüm boyutları ile inceleyip bakım veren, diğer meslek gruplarıyla iş birliği yapabilen ve bireyin çevresel fırsatlarını değerlendirmesine yardımcı olan tek sağlık profesyonelidir. Bu nedenle bireyin sağlık eğitimi ve davranış değiştirmesinde, tüm basamaklarda etkin rol oynamaktadır (Öz Alkan, 2016). Hemşire, riskli gördüğü sağlık davranışlarını tespit eder, değerlendirir ve girişimlerini uygular. Bu nedenle davranış değişimi stratejilerini iyi bilmeli ve uygulayabilmelidir.

Davranış değişikliği, birçok hastalık için risk faktörü olabilecek riskli sağlık davranışlarının birincil önleme yöntemidir ve her birey için özel olmasının yanında karmaşık bir süreçtir. Bireylerin davranış değişikliği için kesin bir model tanımlanmamıştır. Ancak bireylerin davranış değişimine hazır olup olmadıklarını değerlendirmeden yapılan girişimlerin etkisinin düşük olduğu belirtilmiştir. TTM bireylerin değişime hazır olup olmadıklarını değerlendirmenin yanında değişimin hangi aşamasında olduklarını bilmeleri ve o alana özgü

girişim uygulayabilmeleri için hemşireler tarafından kullanılan bir modeldir. TTM birçok kez sağlığı geliştirmek adına hemşireler tarafından test edilmiştir (Karadağlı ve Nahcivan, 2012).

3. Transteoretik Model Literatür İncelemesi

Yapılan sistematik bir incelemede Tip 2 diyabet için Hemoglobin A1c seviyesinin azaltılmasında, diyetlerinin kontrolünde ve egzersize teşvik etmede TTM girişimlerinin etkili olduğu bildirilmiştir (Arafat ve ark., 2016). Yine ülkemizde yapılan bir çalışmada obez bireylerde bireysel olarak uygulanan TTM girişimlerinin fiziksel aktivite ve beslenme davranışında değişikliğin sağlanmasında etkili olduğu belirtilmiştir (Menekli ve ark., 2019). Sadece yetişkinler için değil çocuk ve adölesanlar için de uyarlanarak bisiklet kullanımı, sebze meyve tüketimi, sigara bırakma gibi konularda davranış değişikliği sağladığı ve yararlı bulunduğu belirtilmiştir (Erdem ve Erol, 2020; Erol ve Erdoğan, 2008; Gür ve ark., 2019; Robinson ve Vail, 2012). Sigara kullanan yetişkinler için TTM ölçekleri Türk halkı için geçerli ve güvenilir bulunmuş ve uygulamaları pek çok çalışmada kullanılarak yararlı olduğu belirtilmiştir (Akdeniz, 2019; Koyun ve Eroğlu, 2016; Koyun ve ark., 2015; Taş ve ark., 2016). Fakat yapılan bir sistematik derlemede hemşirelerin TTM kullanarak gerçekleştirdiği girişimlerde bilgi iletişim teknolojilerini yeteri kadar kullanmadıkları bulunmuş ve kişiye özel sağlık müdahaleleri gerçekleştirmek ve daha kolay erişim sağlamak için kullanımını teşvik etmiştir (Lee, Park ve Min, 2015). Sigara bırakma girişimleri için TTM, yetişkinler, adölesanlar, kalp hastaları, akciğer hastaları, gebeler, ebeveynler gibi pek çok farklı grup için kullanılmıştır. Nakamura ve arkadaşları (2004) 20-69 yaş arasındaki yetişkinlerle yaptıkları TTM temelli sigara bırakma girişimlerinin sonucunda, sigara bırakmaya hazır olanların yanında, sigarayı bırakmayı düşünmeyenler için de etkili olduğunu belirtmişlerdir (Nakamura ve ark., 2004). Aveyard ve arkadaşlarının (2006) 16 yaş üzeri gebe kadınlarla TTM kullanılarak yaptıkları girişimlerin sonucunda ise, TTM'nin hazırlık aşamasında olanlarda düşünmeme ve düşünme aşamalarındakilere oranla daha etkili olduğu belirtilmiştir (Aveyard ve ark., 2006). Yine Aveyard ve arkadaşlarının (2009) 18 yaş üstü yetişkinlerle yaptığı bir çalışmada, TTM temelli girişim ve materyallerin standart girişim ve materyallere göre daha etkili olduğunu belirtmişlerdir (Aveyard ve ark., 2009) Thyrian ve arkadaşları (2010) yetişkin gebe kadınlarla TTM temelli motivasyonel görüşmeler yaptıkları çalışmasının sonucunda, motivasyonel girişimin gebe kadınlarda doğru bir yaklaşım olamayabileceği ve bu grup için özel bir yaklaşım geliştirilmesi gerektiğinden bahsetmiştir (Thyrian ve ark., 2010). Bredie ve arkadaşlarının (2011) kardiyovasküler hastalığı olan kişilerle yaptıkları çalışmalarında, TTM temelli motivasyonel görüşmeyi yararlı bulmuştur ve girişim grubunun %26'sı sigarayı bırakmıştır (Bredie ve ark., 2011). Güngörmüş ve Erci'nin (2012) lise öğrencileri ile yaptıkları çalışmasında TTM temelli girişim uygulanan grubun sigara bırakma oranlarının ve aşamalarda ilerlemelerinin daha fazla olduğunu belirtmiştir (Güngörmüs ve Erci, 2012). Mujika ve arkadaşları (2014) 18 yaşından büyük hemşireler ile TTM temelli motivasyonel görüşmeler yaptıkları çalışmasının sonucunda, 15 kişiden 6'sının sigarayı bıraktığını bildirmiş ve motivasyonel görüşmenin sigara bırakmada etkili olduğunu belirtmişlerdir (Mujika ve ark., 2014). Koyun ve Eroğlu (2016) 20-49 yaş arasındaki gebelerle yaptığı çalışmasında ise, TTM temelli sigara bıraktırma eğitiminin gebelerde etkili olduğunu bulmuşlardır (Koyun ve Eroğlu, 2016). Çamözü (2017), 3-6 yaş çocuğu olan ebeveynlerde TTM temelli sigara bıraktırma eğitiminin etkili olduğunu bulmuştur (Çamözü, 2017). Çavuşoğlu (2018), KOAH tanılı 40 yaş üzeri bireyler ile yaptığı çalışmada ise, girişim grubunda, kontrol grubuna göre, sigara bırakma oranlarının yüksek olduğunu ve nikotin bağımlılık oranlarının azaldığını belirtmiştir (Çavuşoğlu, 2018). Khani Jeihooni ve arkadaşlarının (2019), İranlı erkekler ile yaptıkları sigara bırakma çalışmasında, TTM temelli 27 girişimlerin, sigarayı bırakma girişimlerinde artışla etkili olduğunu belirtmiştir (Khani Jeihooni ve ark., 2019).

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HISTORY OF EVIDENCE-BASED NURSING PRACTICE

KANITA DAYALI HEMŞİRELİK UYGULAMALARININ TARİHÇESİ

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ABSTRACT

In recent years, interest in evidence-based practices has gradually increased in order to improve the quality of health services and improve patient care. In this context, evidence-based practices (EBP) in the nursing profession have brought about an important paradigm shift with the effective use of scientific data in clinical decision-making processes. In this paper, the historical development of evidence-based nursing practices, the reasons for their emergence and their aims in practice are discussed.

Evidence-based nursing understanding has taken on a systematic structure with the scientific researches developed in the 20th century, starting with Florence Nightingale's observation-based practices in the battlefields. Especially the studies of Archibald Cochrane and David Sackett formed the theoretical basis of evidence-based health services. This approach, which has become widespread in the field of nursing since the 1990s, has turned into guiding practices in both academic and clinical settings.

Within the scope of this paper, the reasons for the development of evidence-based practices are examined within the framework of the increase in the cost of health services, the expansion of access to information, the change in patient expectations and the reconstruction of trust in health professionals. In addition, the effects of EBP in nursing on patient safety, quality of care, professional accountability and scientific development are evaluated.

In conclusion, evidence-based nursing practice is a holistic approach to improve not only individual patient care but also the overall effectiveness of health systems. In this context, equipping nurses with the knowledge and skills of EBP has become a fundamental requirement for sustainable health services.

Keywords: Evidence-Based Nursing, Clinical Decision-Making, Nursing Practice, Health Care Quality

Giriş

Hemşirelik mesleği, bilimsel bilgi ile insan merkezli bakımın bütünleştiği bir sağlık disiplini olarak, sağlık hizmetlerinde kritik bir role sahiptir. Bu bağlamda, hemşirelik uygulamalarının kanıta dayalı olarak yürütülmesi; bakım kalitesinin artırılması, hasta güvenliğinin sağlanması ve kaynakların etkin kullanımı açısından zorunlu hale gelmiştir (Melnyk & Fineout-Overholt, 2019). Kanıta dayalı hemşirelik (KDH), klinik kararların yalnızca kişisel deneyim ve geleneksel bilgilere değil, aynı zamanda sistematik olarak elde edilmiş bilimsel kanıtlar, klinik uzmanlık ve hasta değerlerinin bir arada değerlendirilmesiyle oluşturulması gerektiğini vurgulayan bir yaklaşımdır (Sackett et al., 1996).

Dünyada 1990'lı yıllardan itibaren yaygınlaşan KDH, Türkiye'de ise hemşirelik eğitiminin üniversite düzeyine taşınması ve lisansüstü programların açılmasıyla birlikte gelişim göstermiştir. Bu gelişimin önemli kilometre taşlarından biri, 1996 yılında kurulan Hemşirelikte Araştırma Geliştirme Derneği ve aynı adlı dergidir. Bu platform, hemşirelik araştırmalarını teşvik etmiş ve bilimsel bilginin uygulamaya aktarılmasını desteklemiştir (Seçkinli, 2015). Türkiye'de KDH terimi literatüre ilk kez Platin (2000) tarafından kazandırılmış, ardından Kara ve Babadağ'ın (2003) çalışmaları ile kavramsal çerçevesi oluşturulmuştur. Bu çalışmalar, KDH'nin yalnızca akademik bir yaklaşım değil, mesleki sorumluluk haline gelmesi gerektiğini vurgulamıştır.

KDH'nin yasal zemini ise 2010 yılında yayımlanan Hemşirelik Yönetmeliği ile güçlenmiştir. Yönetmeliğin 6. maddesinde, hemşirelerin birey, aile ve toplumun sağlıkla ilgili ihtiyaçlarını belirlemesi, bu ihtiyaçlar doğrultusunda kanıta dayalı bakım planlaması, uygulaması ve değerlendirmesi gerektiği açıkça belirtilmiştir (Resmî Gazete, 2010). Ayrıca 2011 yılında Dokuz Eylül Üniversitesi'nde Hemşirelik Araştırma ve Uygulama Birimi'nin kurulması, KDH'nin kurumsallaşmasına yönelik önemli bir adım olmuştur (Aslan & Pekince, 2019). Bu bildiride, Türkiye'de KDH uygulamalarının tarihsel gelişimi ayrıntılı biçimde incelenecek; kavramın kuramsal temelleri, literatürdeki gelişimi, mevzuatsal düzenlemeler ve kurumsal uygulama örnekleri üzerinden, hemşirelik uygulamalarındaki dönüşüm değerlendirilecektir. Böylece, mesleki karar süreçlerinde kanıt kullanımının neden ve nasıl zorunlu hale geldiği tarihsel bağlamda analiz edilecektir.

Kanıt Temelli Hemşirelik Uygulamasının Dünya'da Tarihçesi

1909-1988 yılları arasında yaşamış İskoç bilim insanı, Modern Klinik Epidemiyolojinin babası olarak bilinen Archibald Leman Cochrane, 2. Dünya Savaşında esir düşmüş ve Selanik'te esir kamplarında hekimlik yapmıştır. Bu dönemde yaptığı tedavilerde tedavinin yetersizliği, gereksiz müdahalelerin hastaların hayatını riske atabileceği konuları üzerinde durmuş ve bu durum ona rahatsızlık vermiştir. Bu düşüncelerden yola çıkarak bilimsel araştırmalar konusuna odaklanmıştır. Bu gelişmelerden sonra Kanıta Dayalı Uygulama (KDU), başlangıçta tıp uygulamalarında kullanılmış ve ardından Kanıta Dayalı Tıp (KDT) kavramı ortaya çıkmıştır. İlerleyen süreçte KDT, çeşitli otoriteler tarafından KDU ya da Kanıta Dayalı Sağlık Bakımı (KDSB) olarak kullanılmaya başlanmıştır (Mackey ve Bassendowski, 2017; Sur ve Dahm, 2011).

KDT uygulamalarının ilk olarak 19. Yüzyılda Paris'te başladığı düşünülmektedir. Benzer hastalık tablolarına farklı tedavi yaklaşımları uygulayan hekimler; istedikleri sonuçlara ulaşamamışlardır. Sonuçta bireysel yaklaşımlarına karşı olarak istatistiksel analizlere ve daha önce elde edilen verilere dayanan KDT kavramı gelişmiştir (Claridge & Fabian, 2005)

Cochrane sunulan sağlık hizmetinin; hastaların yararına, hakkaniyetli, uygun maliyetli olması gerektiğine inanıyordu. 1972 yılında yayınladığı "Effectiveness and Efficiency (Etkinlik ve Verimlilik)" isimli kitabında Randomize Kontrollü çalışmaların bu amaca ulaşmak için en iyi yöntem olduğunu savunmuştur. (Cochrane, 1971) Daha sonraki yıllarda bu savunmasını daha ileriye taşımış ve pek çok randomize kontrollü çalışmadan elde edilen sonuçların eleştirel olarak değerlendirilmesiyle daha iyi sonuçlar elde edilebileceğini öne sürmüştür (Shah & Chung, 2009).

KDU kavramı birçok yönü ile "Araştırma Temelli Uygulama" (research based practice) ile bağlantılıdır (Kocaman, 2003). İngiltere'de 1970'li yılların başında hemşirelik araştırmalarında önemli bir ivme katedilmiş ve bu hususta "Briggs Report'ta" yer alan önerilerin etkisi olmuştur. "Briggs Report'ta" İngiliz hemşireliğinin araştırma temelli meslek olmasını önermektedir (Chapman, 1973). Bu yüzden 1970'li yılların ortalarından sonra kaleme alınan hemşirelik araştırmalarının sayısında önemli artışlar olmuştur. Fakat, yapılan araştırmalarda elde edilen sonuçlarının hemşirelik uygulamalarında kullanılma yetersizliği yoğun bir şekilde sıkıntı yaratmaya başlamıştır (French, 2002).

Aslında KDU, 1800'lerde Florence Nightingale'den, 1970'lerin başlarında kanıta dayalı tıp hareketine ve 1990'ların sonunda hemşirelik mesleğine doğru evrilmiştir (Mackey & Bassendowski, 2017). Florence Nightingale'nin 1850-1860'lı yıllarda hemşireliği geliştirmek, ölüm oranlarını azaltmak ve sağlığı geliştirmek amacıyla yaptığı çalışmalar; araştırmalara, uygulamalara temel olma özelliği taşımaktadır. Kırım savaşındaki tecrübesinden sonra, yaptığı birçok kanıta dayalı uygulama girişimleri ile hasta sonuçlarına etkisini incelemiştir (Mackey & Bassendowski, 2017). Nightingale'nin o dönemde güçlü kanıtlarla hasta sonuçlarının iyileştirme kavramını başlattığı kabul edilmektedir (Karabulut ve ark., 2019; Mackey & Bassendowski, 2017). İlk kez 1859'da yayınlanan "Hemşirelik Üzerine Notlar" isimli kitabında, deneye ve gözleme dayalı bilgilerden bahsetmiştir. Kanıta dayalı uygulama teriminin o dönemde tanınmamasına rağmen Nightingale, eleştirel inceleme ve deneyler yöntemleriyle saptanan kanıtları kullanılmaktaydı. Dönemin hemşireleri için "Hemşirelik Üzerine Notlar" kitabı, en iyi klinik uygulama kılavuzu olarak kabul edilmiştir (Karabulut ve ark., 2019; Katowa-Mukwato ve ark., 2021; Mackey & Bassendowski, 2017). Nightingale hemşirelik disiplini için kanıta dayalı uygulamanın öncüsüdür (Katowa-Mukwato ve ark., 2021; Mackey & Bassendowski, 2017). Fakat Nightingale'nin kanıta dayalı uygulamalar hakkındaki fikirleri 20. yy başlarına kadar hemşirelikte yer almamıştır (Berman ve ark., 2016). 1900'lü yıllarda halen birçok hemşirelik uygulamasının deneyim, sağduyu, gelenek, sezgi ve test edilmemiş teorilere dayandığı söylenmektedir (French, 1999; Kara ve Babadağ, 2003).

Dünya Sağlık Örgütü (DSÖ) 1948 yılında sağlıkta birlik ve "Herkes İçin Sağlık" amacıyla hizmet vermeye başlayarak sağlıkta düşünmeyi ve uygulama yapmayı sağlamıştır (Mahler, 1988). Çoğunluğunu geleneksel uygulamaların oluşturduğu 1960'lı yıllarda sağlık hizmetlerinde yaşanan mali sıkıntılar, artan tıbbi hataların yanı sıra gelişen teknoloji, ulaşılan bilgi miktarı gibi etmenler kalıcı değişikliklere gidilmesi gerekliliğini ortaya çıkarmış bu konu yavaş yavaş önemini artırmıştır. Hemşirelikte araştırma kavramına ilk kez Ketefian'ın çalışmalarında rastlanılmış, ayrıca 1970'li yıllarda araştırma ve uygulama adına "Conduct and Utilization of Research in Nursing" (CURN) ve "Wester Interstate Commission for Higher Education in Nursing" (WICHEN) gibi projeler başlatılmıştır. KDU, Cochrane'ın 1970'li yılların başında bakım kararlarının fikir veya deneyimlerden ziyade, kanıta dayalı olmasının gerekliliğini belirtmesi ile başlamıştır (Arslan Yürümezoğlu ve Kocaman, 2008; Erişen ve ark., 2019; Evcimen ve İşcan Ayyıldız, 2019; Karabulut ve ark., 2019; Taş Arslan ve Çelen, 2018; Seçkinli, 2015). Temel hemşirelik araştırmalarının ve klinik hemşirelik araştırmalarının

yapılması ve bulguların yayılması, ulusal düzeyde hemşirelik araştırmalarının görünür olmasının sağlanması amacıyla ABD'de "Hemşirelik Araştırmaları Ulusal Merkezi (National Center for Nursing Research- NCNR)" 1985 yılında kurulmuştur. Yine aynı yıl hemşirelikte araştırma kullanımı ve geliştirilmesine yönelik ilk rehberler ICN tarafından yayınlanmıştır (Karabulut ve ark., 2019). "David Sackett'in" 1990'ların başında ilaç seçiminde KDU'yu önermesi, KDU'ların asıl başlangıcı olarak kabul edilmektedir (Sur ve Dahm, 2011). Terimin literatürde kullanımı 1992 yıllarında olmuş, 1993 yılında İngiltere'de ise sağlıkla ilgili kararlar almak için yüksek kalitedeki bilgileri kullanmak isteyen herkesin ulaşabilmesini, kanıt üreten, kanıtları ulaşılabilir kılmak gibi hedefleri olan Cochrane Kurumu (Cochrane Collaboration) kurulmuştur (Chalmers, 1993; Cullum ve ark., 2007; Suçin, 2006). Zamanla dünyada hemşirelik alanında da kullanımı hızlanmış ve 1996 yılında hemşire kurucusu olduğu bilinen dünyanın en büyük araştırma odağı olan Joanna Bridggs Enstitüsü (JBI) kurulmuştur ve yayınlanan raporlarında araştırma temelli hizmetin önemi vurgulanmıştır (Joanna Briggs Institute, 2003; Zhou ve ark., 2016). Sonrasında ise kurum örneklerine İngiltere, Kanada, ABD, Almanya, Yeni Zelanda ve Avustralya gibi ülkelerde de rastlanmıştır. Bu kurumlarda eğitim programları düzenlenip, sistematik incelemeler ve KDU rehberleri oluşturulmuştur (Kathleen, 2013; Kocaman, 2003; Melynk ve ark., 2008; Petushek ve ark., 2019). Teknolojinin gelişmesi ise kurumsallıktan online hizmete geçişi artırmış ve daha ulaşılabilir olma yolunu açmıştır. 1998'de Kanıta Dayalı Hemşirelik Dergisi yayınlanmaya başlamış, Yeni Zelanda, Kanada ve İngiltere'de KDH merkezleri kurulmuştur (Kara ve Babadağ, 2003; Kocaman, 2003). Avrupa'da Stetler ve Marram klinik araştırmaların iyileştirilmesi, hemşirelikte araştırma kullanımı, araştırma bulgularının uygulamaya aktarılması amacıyla ilk hemşirelik modelini geliştirmiş, bu model birçok hemşireye klinik kılavuz olmuştur (Karabulut ve ark., 2019; Stetler, 2001; Şenyuva, 2016).

Hollanda'da 2012 yılında Hollandalı Profesyonel Hemşireler Standardı yayımlanmış, Martini Hastanesi'nde "Hemşireler için Kanıta Dayalı Uygulama" eğitimi oluşturulmuştur (van der Goot ve ark., 2018). KDH'ye dikkat çekebilmek adına "Uluslararası Hemşireler Birliği" (ICN) de 2012 yılı temasını "Kanıttan Eyleme" olarak belirlemiştir (Türk Hemşireler Derneği, 2012). 2005 yılında KDH enstitüsü olarak açılıp Joanna Briggs Instıtute (JBI) modeli olarak bilinen kanıta dayalı sağlık hizmeti modeli herkes tarafından kullanılmaya başlanmış bu model yönetim kurulu kararı ile bir dizi değişimler geçirmiş 2016 yılında güncellenmiştir. (Joanna Briggs Institute, 2003). KDU gerek tıbbi hatalar gerek SBH maliyeti gerekse kişilerin kaliteli SBH istemesinden kaynaklı son 20 yılda önem kazanmış, dikkat çekebilmek adına çalışmalar yapılmış, kılavuzlar geliştirilmiş, bilimsel toplantılar düzenlenmiştir (Aslan, 2018; Karabulut ve ark., 2019; Katowa-Mukwato ve ark., 2021).

1.1.Kanıt Temelli Hemşirelik Uygulamalarının Türkiye'de Tarihçesi

Kanıta dayalı hemşirelik uygulamaları (KDH), dünya genelinde olduğu gibi Türkiye'de de hemşirelik mesleğinin profesyonelleşme süreciyle birlikte gelişmeye başlamıştır. Türkiye'de bu sürecin başlangıcı, özellikle 1960'lı yıllarda hemşirelik eğitim sisteminde yaşanan yapısal değişimlerle birlikte ivme kazanmıştır. Bu dönemde hemşirelik eğitiminin lise düzeyinden üniversite düzeyine taşınması, mesleki eğitimin bilimsel temeller üzerine inşa edilmesine olanak sağlamıştır. 1980'li yıllardan itibaren ise hemşirelikte lisansüstü eğitim programlarının açılması, hemşirelikte araştırma kültürünün gelişmesine ve bilimsel bilgi üretiminin artmasına katkı sağlamıştır. Bu bağlamda, akademik gelişmeler, hemşirelerin klinik kararlarında bilimsel kanıtları temel almalarını teşvik etmiş ve kanıta dayalı uygulamaların altyapısını hazırlamıştır.

Türkiye'de kanıta dayalı uygulama (KDU) kavramı hemşirelik literatürüne ilk olarak 2000'li yıllarda Platin'in (2000) çalışmalarıyla girmiştir. Platin'in bu öncü çalışmaları, KDU'nun

Türkiye'deki hemşirelik terminolojisine kazandırılması açısından önemlidir. Kısa bir süre sonra Kara ve Babadağ (2003) tarafından yayımlanan "Kanıta Dayalı Hemşirelik" başlıklı makalede ise kavramın temel tanımı yapılmış, kuramsal çerçevesi çizilmiş ve klinik uygulamalarda kullanımına dair örnekler sunulmuştur. Aynı yıl Kocaman (2003) da benzer şekilde KDH'nin kuramsal yönüne ilişkin katkılar sunmuş ve kavramın uygulamadaki yerini tartışmaya açmıştır. Bu akademik girişimler, KDH'nin Türkiye'de anlaşılması ve yaygınlaşması açısından mihenk taşı niteliğindedir. KDH'nin kurumsal düzeyde tanınması ve mesleki sorumluluk haline gelmesi ise 2010 yılında yürürlüğe giren Hemşirelik Yönetmeliği ile yasal bir zemin kazanmıştır. Yönetmeliğin 6. maddesinde şu ifade yer almaktadır: "Her ortamda bireyin, ailenin ve toplumun hemşirelik girişimleri ile karşılanabilecek sağlıkla ilgili ihtiyaçlarını belirler ve hemşirelik tanılama süreci kapsamında belirlenen ihtiyaçlar çerçevesinde hemşirelik bakımını kanıta dayalı olarak planlar, uygular, değerlendirir ve denetler" (Hemşirelik Yönetmeliği, 2010). Bu düzenleme, kanıta dayalı uygulamaların yalnızca akademik bir ideal değil, aynı zamanda mesleki bir zorunluluk haline geldiğini göstermektedir.

KDH'nin sistematik biçimde kurumsallaşması ise 2011 yılında Dokuz Eylül Üniversitesi'nde kurulan Hemşirelik Araştırma ve Uygulama Birimi ile somut hale gelmiştir. Bu birim, Hemşirelik Fakültesi ile Hemşirelik Hizmetleri Müdürlüğü iş birliğinde kurulmuş olup; amacı, hastane ortamlarında kanıta dayalı uygulamaların entegrasyonunu sağlamak, hemşirelerin araştırma okuryazarlığını geliştirmek ve klinik kararlarında bilimsel verileri kullanmalarını teşvik etmektir. Bu merkez aynı zamanda, akademi ve saha arasında güçlü bir köprü kurarak, araştırma bulgularının bakım hizmetlerine yansıtılmasını mümkün kılmıştır (Aslan & Pekince, 2019). Bu gelişmeler, Türkiye'de hemşirelik uygulamalarının geleneksel bilgiye dayalı tutumlardan uzaklaşarak, sistematik literatür taramalarına, klinik rehberlere, meta-analiz ve randomize kontrollü çalışmalar gibi yüksek düzeydeki bilimsel kanıtlara dayalı hale gelmesini sağlamıştır. Nitekim Skela-Savič ve arkadaşlarının (2020) belirttiği gibi, kanıta dayalı uygulamaların yaygınlaşması, hemşirelerin klinik kararlarda daha özgüvenli davranmasını sağlamakta ve bakım kalitesini artırmaktadır (Skela-Savič ve ark., 2020). Sonuç olarak, Türkiye'de KDH uygulamaları, hemşirelik eğitimi ve mevzuatındaki değişimlerle desteklenmiş; akademik üretkenlik ve kurumlar arası iş birlikleri ile profesyonel bir boyuta taşınmıştır. Bugün gelinen noktada, kanıta dayalı hemşirelik yalnızca bir ideal değil, mesleğin temel dayanaklarından biri haline gelmiştir.

Sonuç

Kanıta dayalı hemşirelik uygulamaları, modern sağlık hizmetlerinin kalite, güvenlik ve etkililik ilkeleri doğrultusunda şekillenmesinde kilit bir rol oynamaktadır. Hemşirelik mesleğinin bilimsel temellere dayalı biçimde kurumsallaşması ve meslek etiğiyle bütünleşmesi, kanıt kullanımını yalnızca bir tercih değil, aynı zamanda profesyonel bir zorunluluk haline getirmiştir. Türkiye'de bu sürecin gelişimi, hem eğitim sistemindeki dönüşümler hem de yasal düzenlemeler ile desteklenmiş; akademik çalışmalar ve kurumsal uygulama örnekleri sayesinde giderek yaygınlaşmıştır. 1960'lı yıllardan itibaren yükseköğretime taşınan hemşirelik eğitimi, 1990'lı yıllarda lisansüstü programlarla güç kazanmış; bilimsel araştırma kültürüyle birlikte kanıta dayalı düşünme biçiminin temelini oluşturmuştur. 1996 yılında kurulan Hemşirelikte Araştırma Geliştirme Derneği ve dergisi, bilimsel üretimin uygulamaya aktarılmasına önemli katkılar sunmuştur. Türkiye'de KDH terimi ilk kez 2000'li yıllarda literatüre girmiş; Platin'in öncü çalışmaları ile başlayan bu süreç, Kara ve Babadağ'ın kuramsal katkılarıyla şekillenmiştir. 2010 yılında yayımlanan Hemşirelik Yönetmeliği ise, kanıta dayalı bakımın yasal bir zorunluluk olduğunu açıkça ifade ederek, bu yaklaşımı mesleki sorumluluk haline getirmiştir.

2011 yılında Dokuz Eylül Üniversitesi'nde kurulan Hemşirelik Araştırma ve Uygulama Birimi, KDH'nin kurumsallaşmasında önemli bir dönüm noktası olmuş; akademi-saha iş birliğinin güçlendirilmesiyle klinik kararların bilimsel veriye dayandırılması yönünde model oluşturmuştur. Bu gelişmeler, hemşirelik mesleğinin yalnızca uygulayıcı değil, aynı zamanda bilimsel bilgi üretici ve yorumlayıcı bir rol üstlenmesini sağlamıştır. Günümüzde hemşirelik uygulamalarında en güncel bilimsel kanıtların sistematik biçimde kullanılması, hasta merkezli bakımın kalitesini doğrudan artırmakta ve klinik güvenliği sağlamaktadır. Bu bağlamda, KDH'nin yalnızca tarihsel bir gelişim çizgisi değil, aynı zamanda mesleki kimliğin dönüşüm süreci olduğu anlaşılmaktadır. Türkiye'de bu yaklaşımın sürdürülebilirliği için hem hemşirelik müfredatlarının kanıt temelli eğitim anlayışıyla yeniden yapılandırılması, hem de klinik alanda çalışan hemşirelerin sürekli mesleki gelişimlerinin desteklenmesi gerekmektedir. Kanıta dayalı uygulamalar, hemşirelik mesleğinin geleceğinde bilgi, değer ve bakımın bütünleştiği etik ve bilimsel bir yol haritası sunmaktadır.

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NEXT-GENERATION MOLECULAR DIAGNOSTICS FOR PLANT PATHOGEN DETECTION: INNOVATIONS, APPLICATIONS, AND FUTURE PERSPECTIVES

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ABSTRACT

Timely and accurate detection of plant pathogens is critical to global food security and sustainable agriculture. Traditional diagnostic approaches, though widely used, are often limited by their low sensitivity, specificity, and inability to detect pathogens at early stages. Next-generation molecular diagnostics have revolutionized plant pathology by enabling rapid, specific, and highly sensitive detection of diverse plant pathogens. This review explores the evolution and application of advanced molecular tools, including PCR, qPCR, LAMP, and next-generation sequencing (NGS), as well as emerging technologies such as CRISPR-Cas-based diagnostics and portable biosensors. Integration of isothermal amplification with CRISPR-Cas12a/13 systems has demonstrated significant promise for field-deployable assays. Additionally, AI-driven platforms and lab-on-a-chip innovations are expanding the accessibility and efficiency of diagnostic practices. The application of these tools in disease surveillance, quarantine management, and resistance breeding underscores their growing importance in modern agriculture. Despite ongoing challenges such as high costs, sample preparation limitations, and the need for skilled personnel, future advancements in multiplexing, automation, and affordability are expected to broaden their global impact. This review highlights the current landscape, recent breakthroughs, and future trajectories of molecular diagnostics in plant disease detection, offering a roadmap for enhancing crop protection and biosecurity.

Keywords: Molecular diagnostics, Plant pathogens, CRISPR-Cas, Sustainable agriculture, Field diagnostics, Precision agriculture.

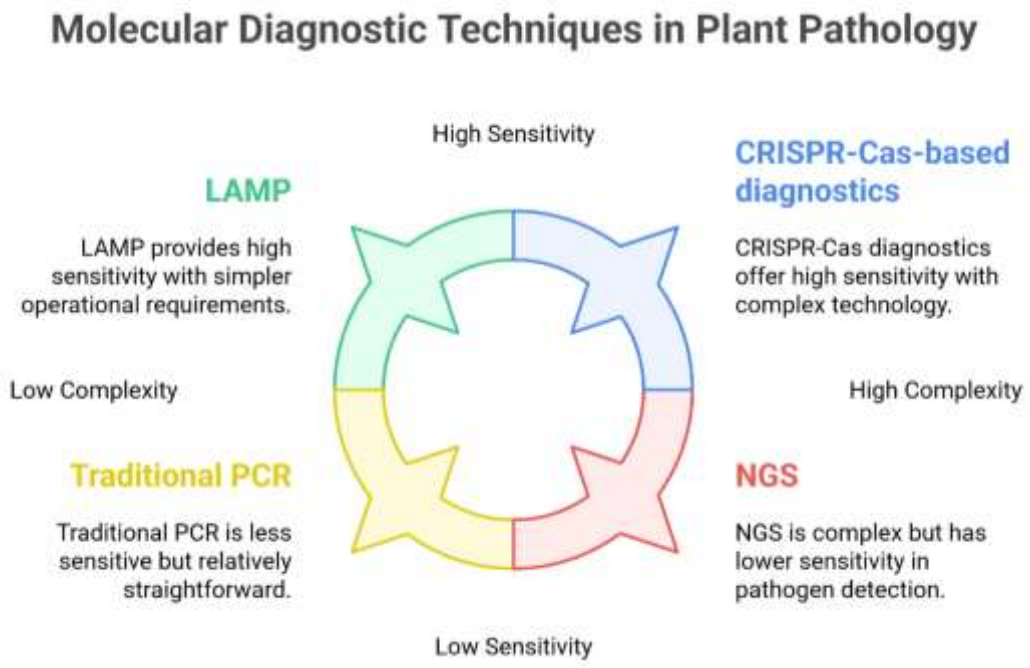
BİTKİ PATOJENLERİNİN TESPİTİ İÇİN YENİ NESİL MOLEKÜLER TEŞHİS: YENİLİKLER, UYGULAMALAR VE GELECEK PERSPEKTİFLERİ

ÖZET

Bitki patojenlerinin zamanında ve doğru tespiti, küresel gıda güvenliği ve sürdürülebilir tarım için kritik öneme sahiptir. Geleneksel teşhis yaklaşımları, yaygın olarak kullanılmalarına rağmen, genellikle düşük hassasiyetleri, özgüllükleri ve patojenleri erken aşamalarda tespit edememeleri ile sınırlıdır. Yeni nesil moleküler teşhis yöntemleri, çeşitli bitki patojenlerinin hızlı, spesifik ve son derece hassas bir şekilde tespit edilmesini sağlayarak bitki patolojisinde devrim yaratmıştır. Bu derlemede PCR, qPCR, LAMP ve yeni nesil dizileme (NGS) gibi gelişmiş moleküler araçların yanı sıra CRISPR-Cas tabanlı teşhis ve taşınabilir biyosensörler gibi yeni teknolojilerin gelişimi ve uygulamaları incelenmektedir. İzotermal amplifikasyonun CRISPR-Cas12a/13 sistemleri ile entegrasyonu, sahada konuşlandırılabilir testler için önemli bir umut vaat etmiştir. Ayrıca, yapay zeka odaklı platformlar ve çip üzerinde laboratuvar inovasyonları, teşhis uygulamalarının erişilebilirliğini ve verimliliğini artırmaktadır. Bu araçların hastalık gözetimi, karantina yönetimi ve direnç ıslahında uygulanması, modern tarımda artan önemlerinin altını çizmektedir. Yüksek maliyetler, numune hazırlama sınırlamaları ve kalifiye personel ihtiyacı gibi süregelen zorluklara rağmen, gelecekte çoklama, otomasyon ve satın alınabilirlik alanlarındaki ilerlemelerin küresel etkilerini genişletmesi beklenmektedir. Bu derleme, bitki hastalıklarının tespitinde moleküler teşhisin mevcut durumunu, son atılımları ve gelecekteki yörüngelerini vurgulayarak, mahsul korumasını ve biyogüvenliği artırmak için bir yol haritası sunmaktadır.

Anahtar Kelimeler: Moleküler teşhis, Bitki patojenleri, CRISPR-Cas, Sürdürülebilir tarım, Arazi teşhisi, Hassas tarım.

GRAPHICAL ABSTRACT



1. INTRODUCTION TO MOLECULAR DIAGNOSTICS IN PLANT PATHOLOGY

Plant diseases significantly impact global agriculture, leading to substantial economic losses and threatening food security. Traditional diagnostic methods, such as visual inspections and culture-based techniques, often lack sensitivity and specificity, resulting in delayed or inaccurate pathogen identification. Molecular diagnostics have emerged as powerful tools, offering rapid, sensitive, and specific detection of plant pathogens (Donoso and Valenzuela, 2018). These techniques enable early intervention, reducing the spread of diseases and minimizing crop losses.

Polymerase Chain Reaction (PCR) and its variants have been widely adopted for detecting a broad range of plant pathogens (Shahrajabian and Sun, 2024). However, PCR-based methods require sophisticated equipment and trained personnel, limiting their field applicability. Isothermal amplification techniques, such as Loop-mediated Isothermal Amplification (LAMP), have addressed some of these limitations by enabling rapid amplification at a constant temperature, facilitating on-site diagnostics. Recent advancements have introduced CRISPR-based diagnostics, leveraging the specificity of CRISPR-Cas systems for nucleic acid detection (Hassan et al., 2025). These systems offer high sensitivity and specificity, with potential for point-of-care applications. Integration of CRISPR diagnostics with isothermal amplification methods has further enhanced their utility in field settings. The convergence of molecular diagnostics with digital technologies and artificial intelligence (AI) is poised to revolutionize plant disease management (Wei et al., 2024). AI-driven analysis of diagnostic data can improve accuracy, reduce interpretation time, and facilitate large-scale disease surveillance. These innovations underscore the importance of molecular diagnostics in modern agriculture.

2. CURRENT MOLECULAR DETECTION TECHNIQUES

Molecular detection techniques have transformed plant pathology by enabling precise identification of pathogens at the genetic level (Zanatta et al., 2025). PCR remains a cornerstone method, allowing amplification of specific DNA sequences for pathogen detection. Quantitative PCR (qPCR) and Reverse Transcription PCR (RT-PCR) have enhanced sensitivity and enabled quantification of pathogen load (Wang et al., 2024). Despite their advantages, PCR-based methods require thermal cyclers and are susceptible to inhibitors present in plant tissues. Isothermal amplification techniques, such as LAMP, have addressed these challenges by operating at a constant temperature, eliminating the need for complex equipment. LAMP assays have been developed for various pathogens, including Phytophthora infestans and Pseudomonas syringae, demonstrating high sensitivity and specificity. Recombinase Polymerase Amplification (RPA) is another isothermal method that enables rapid DNA amplification at low temperatures (Kurbatov et al., 2024). RPA has been combined with lateral flow assays for field-deployable diagnostics. DNA microarrays and hybridization-based methods allow simultaneous detection of multiple pathogens but are limited by their complexity and cost.

Next-Generation Sequencing (NGS) offers comprehensive analysis of plant microbiomes, facilitating the identification of known and novel pathogens (Hima Parvathy et al., 2024). However, NGS is resource-intensive and requires bioinformatics expertise. Advancements in portable sequencing technologies are making NGS more accessible for field applications. Overall, current molecular detection techniques provide a robust framework for pathogen identification, with ongoing innovations enhancing their applicability and efficiency.

3. EMERGING AND ADVANCED TECHNOLOGIES

Emerging technologies are pushing the boundaries of plant pathogen diagnostics, offering unprecedented sensitivity, specificity, and speed. CRISPR-based diagnostics have garnered significant attention, utilizing the programmable nature of CRISPR-Cas systems for nucleic acid detection (Jaybhaye et al., 2024). Systems like SHERLOCK and DETECTR employ Cas enzymes to recognize specific DNA or RNA sequences, triggering a detectable signal. CRISPR diagnostics have been applied to detect various plant pathogens, including viruses and fungi. For instance, a CRISPR-Cas12a-based assay was developed for rapid detection of *Phytophthora nicotianae*, demonstrating high sensitivity and specificity (Zang et al., 2024). Similarly, a LAMP-CRISPR-Cas12a integrated assay was established for *Xylella fastidiosa* detection, enabling field-deployable diagnostics.

Biosensors and lab-on-a-chip technologies are also emerging as powerful tools for plant pathogen detection (Lu et al., 2024; Nagaraju et al., 2024). These devices integrate microfluidics, optics, and electronics to perform complex analyses on a compact platform. They offer rapid, sensitive, and multiplexed detection capabilities, suitable for on-site applications. The integration of AI with molecular diagnostics is enhancing data analysis and interpretation (Sheikh et al., 2024). AI algorithms can process complex datasets, identify patterns, and provide actionable insights, facilitating real-time decision-making in disease management. These advancements are paving the way for precision agriculture and improved plant health monitoring.

4. APPLICATIONS IN AGRICULTURE AND DISEASE SURVEILLANCE

The application of molecular diagnostics in agriculture has significantly improved disease surveillance and management. Rapid and accurate detection of pathogens enables timely interventions, reducing crop losses and improving yield. Field-deployable diagnostics, such as CRISPR-based lateral flow assays, have been successfully used to detect pathogens like *Puccinia striiformis* and *Magnaporthe oryzae* in wheat (Dhavale et al., 2025). These tools facilitate on-site testing, allowing farmers and agronomists to make informed decisions promptly. Integration with mobile devices and cloud-based platforms enhances data collection and sharing, supporting large-scale disease monitoring. Such systems contribute to early warning networks and coordinated responses to disease outbreaks. Molecular diagnostics also play a crucial role in quarantine and biosecurity measures (Raji and Aliyu, 2025). Sensitive detection methods are essential for identifying and managing quarantine pathogens, preventing their spread across regions. For example, CRISPR-Cas12a-based assays have been developed for detecting *Phytophthora ramorum*, a pathogen of significant quarantine concern. In breeding programs, molecular diagnostics assist in selecting disease-resistant cultivars by identifying specific genetic markers. This accelerates the development of resilient crop varieties, enhancing food security. Overall, the integration of molecular diagnostics into agricultural practices is transforming plant disease management and surveillance.

5. CHALLENGES, INNOVATIONS, AND FUTURE DIRECTIONS

Despite significant advancements, several challenges hinder the widespread adoption of molecular diagnostics in plant pathology. High costs, technical complexity, and the need for specialized equipment limit accessibility, particularly in resource-constrained settings. Efforts are underway to develop cost-effective, user-friendly diagnostic tools suitable for field use. Sample preparation remains a bottleneck, as plant tissues often contain compounds that inhibit nucleic acid amplification. Simplifying and standardizing extraction protocols is essential for reliable diagnostics. Advancements in direct detection methods and inhibitor-resistant enzymes are addressing these issues. Multiplexing capabilities are crucial for detecting multiple pathogens simultaneously. While CRISPR-based diagnostics offer high specificity, their multiplexing potential is currently limited. Research is focused on developing strategies to expand multiplexing, such as using orthogonal Cas enzymes and engineered guide RNAs.

Integration with AI and digital technologies holds promise for enhancing diagnostic accuracy and scalability. AI-driven platforms can automate data analysis, reduce human error, and facilitate real-time disease monitoring. Additionally, portable and connected devices enable rapid data sharing and coordinated responses to disease outbreaks. Future directions include the development of universal diagnostic platforms capable of detecting a wide range of pathogens with minimal user intervention. Emphasis on sustainability, affordability, and accessibility will drive innovations, ensuring that molecular diagnostics benefit diverse agricultural systems globally.

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HARNESSING THE POWER OF SOIL MICROBES: A MINI-REVIEW ON THEIR ROLE IN PLANT GROWTH PROMOTION AND HEALTH

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ABSTRACT

Soil microorganisms play a pivotal role in promoting plant growth, enhancing nutrient acquisition, and defending against biotic and abiotic stresses. This mini-review explores the multifaceted interactions between soil microbes and plants, focusing on the rhizosphere as a dynamic hub of microbial activity. Key microbial groups, including plant growth-promoting rhizobacteria (PGPR) and mycorrhizal fungi, are highlighted for their direct and indirect roles in nutrient cycling, hormone production, and biocontrol of pathogens. The review also emphasizes the importance of microbial antagonism in natural disease suppression and the potential of integrating beneficial microbes into sustainable agricultural practices. Advances in omics technologies and the development of microbial consortia are opening new avenues for precision agriculture. Overall, leveraging the power of soil microbes presents a promising strategy to improve plant health, reduce chemical inputs, and support global food security.

Keywords: Soil microbes, Plant growth-promoting rhizobacteria (PGPR); Mycorrhizal fungi, Sustainable agriculture, Plant-microbe interactions.

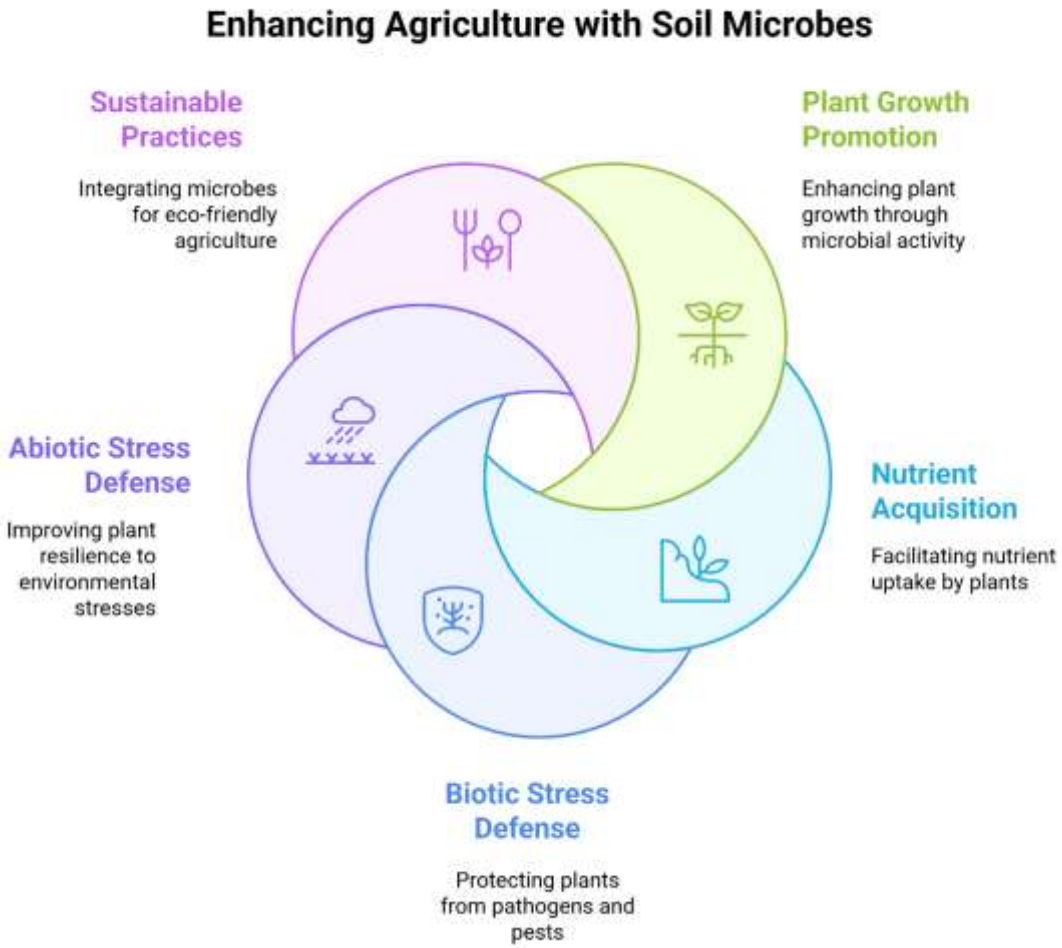
TOPRAK MİKROPLARININ GÜCÜNDEN YARARLANMAK: BİTKİ BÜYÜMESİNİN TEŞVİKİ VE SAĞLIĞINDAKİ ROLLERİ ÜZERİNE MİNİ BİR İNCELEME

ÖZET

Toprak mikroorganizmaları bitki büyümesini teşvik etmede, besin alımını artırmada ve biyotik ve abiyotik streslere karşı savunmada önemli bir rol oynar. Bu mini inceleme, toprak mikroorganizmaları ve bitkiler arasındaki çok yönlü etkileşimleri inceler ve mikrobiyal aktivitenin dinamik bir merkezi olarak rizosfere odaklanır. Bitki büyümesini teşvik eden rizobakteriler (PGPR) ve mikorizal funguslar dahil olmak üzere temel mikrobiyal gruplar, besin döngüsünde, hormon üretiminde ve patojenlerin biyolojik kontrolünde doğrudan ve dolaylı rolleri nedeniyle vurgulanır. İnceleme ayrıca doğal hastalık baskılamasında mikroorganizma antagonizmanın önemini ve faydalı mikroorganizmaları sürdürülebilir tarım uygulamalarına entegre etme potansiyelini vurgular. Omiks teknolojilerindeki ilerlemeler ve mikrobiyal konsorsiyumların geliştirilmesi, akıllı tarım için yeni yollar açıyor. Genel olarak, toprak mikroplarının gücünden yararlanmak, bitki sağlığını iyileştirmek, kimyasal girdileri azaltmak ve küresel gıda güvenliğini desteklemek için umut verici bir strateji sunmaktadır.

Anahtar kelimeler: Toprak mikroorganizmaları, Bitki büyümesini teşvik eden rizobakteriler (PGPR); Mikorizal funguslar, Sürdürülebilir tarım, Bitki-mikroorganizma etkileşimleri.

GRAPHICAL ABSTRACT



1. INTRODUCTION: THE RHIZOSPHERE AS A HOTSPOT OF MICROBIAL ACTIVITY

The rhizosphere, the narrow region of soil influenced by root secretions and associated microbial activity, is a dynamic environment where complex interactions between plants and microorganisms occur. This zone is teeming with a diverse array of soil microbes, including bacteria, fungi, archaea, and actinomycetes, which play pivotal roles in plant health and soil fertility (Akbar et al., 2025). Plants exude a variety of organic compounds, such as sugars, amino acids, and organic acids, into the rhizosphere, which serve as nutrients for microbial communities. In return, these microbes contribute to plant growth by facilitating nutrient acquisition, producing phytohormones, and protecting against pathogens. The mutualistic relationships established in the rhizosphere are fundamental to plant development and resilience. Recent studies have highlighted the significance of these interactions. For instance, microbial fertilizers have been shown to enhance soil physicochemical properties and promote plant growth by increasing microbial richness and maintaining soil microecological balance (Abdellatif et al., 2024). Additionally, the application of plant growth-promoting rhizobacteria (PGPR) has been associated with improved crop productivity and adaptation to changing climates (Chen et al., 2024).

Understanding the mechanisms underlying these beneficial interactions is crucial for developing sustainable agricultural practices. Advances in omics technologies, such as metagenomics and transcriptomics, have provided insights into the complex networks of gene expression and metabolic pathways involved in plant-microbe interactions (Jain et al., 2024; Srikanth et al., 2025). These tools have enabled researchers to identify key microbial taxa and functions that contribute to plant health. Furthermore, the role of soil microbes extends beyond individual plant benefits. They are integral to ecosystem functions, including nutrient cycling, soil structure maintenance, and carbon sequestration. For example, certain mycorrhizal fungi have been found to play a significant role in carbon capture, surpassing the contribution from decomposed plant matter (Basiru and Hijri, 2024). Despite the recognized benefits, challenges remain in harnessing soil microbes for agriculture. Factors such as soil type, climate, and farming practices influence microbial communities and their functions. Therefore, site-specific strategies are necessary to effectively utilize microbial inoculants and amendments. In conclusion, the rhizosphere is a critical zone where beneficial plant-microbe interactions occur, significantly influencing plant growth and soil health. Continued research and technological advancements are essential for unlocking the full potential of soil microbes in promoting sustainable agriculture.

2. PLANT GROWTH-PROMOTING RHIZOBACTERIA (PGPR): KEY MECHANISMS AND EXAMPLES

Plant growth-promoting rhizobacteria (PGPR) are a group of beneficial bacteria that colonize plant roots and enhance growth through various direct and indirect mechanisms (Ajinde et al., 2024). These microbes have garnered attention for their potential to reduce reliance on chemical fertilizers and pesticides, thereby contributing to sustainable agriculture. PGPR facilitate the uptake of essential nutrients. For instance, they can fix atmospheric nitrogen, solubilize phosphates, and mobilize potassium and zinc, making these nutrients more available to plants. Many PGPR synthesize plant hormones such as indole-3-acetic acid (IAA), gibberellins, and cytokinins, which stimulate root elongation and branching, enhancing nutrient and water absorption (Ehinmitan et al., 2024; Hyder et al., 2024). By producing the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase, PGPR lower ethylene levels in plants, a hormone associated with stress responses, thereby promoting root growth under stress conditions. PGPR protect plants by producing antibiotics, siderophores, and lytic enzymes that inhibit pathogenic microbes (Benaissa, 2024). For example, certain strains produce lipopeptides and polyketides with antifungal properties. PGPR can trigger a plant's innate defense mechanisms, enhancing resistance to a broad spectrum of pathogens without causing disease themselves (Sheoran et al., 2025). The production of extracellular polymeric substances (EPS) by PGPR aids in biofilm formation on root surfaces, providing a protective barrier against environmental stresses and pathogens. *Azospirillum* and *Azotobacter* species have been shown to promote growth and enhance salt tolerance in crops like cherry tomato under salinity stress (Jia et al., 2025). *Bacillus subtilis* strains produce volatile organic compounds that stimulate root development and have been used to enhance plant growth under various conditions (Dutta et al., 2025). *Pseudomonas fluorescens* is known for its biocontrol properties, protecting roots against parasitic fungi and producing compounds like 2,4-diacetylphloroglucinol (2,4-DAPG) with antiphytopathogenic activity (Allende-Molar et al., 2025). The integration of PGPR into agricultural practices offers a promising avenue for enhancing crop yields, improving stress tolerance, and reducing chemical inputs. However, the effectiveness of PGPR can be influenced

by environmental factors, and further research is needed to optimize their application across diverse agroecosystems.

3. MYCORRHIZAL FUNGI: ENHANCING NUTRIENT UPTAKE AND PLANT HEALTH

Mycorrhizal fungi form symbiotic associations with plant roots, playing a crucial role in nutrient acquisition, stress tolerance, and overall plant health (Ahmed et al., 2025). These fungi extend the root systems reach, facilitating the uptake of water and nutrients, particularly phosphorus and micronutrients.

Types of Mycorrhizal Associations: Arbuscular mycorrhizal fungi (AMF) penetrate root cortical cells, forming arbuscules that are sites of nutrient exchange (Bhupenchandra et al., 2024). AMF are widespread and associate with a majority of terrestrial plants. Ectomycorrhizal fungi (EMF) form a sheath around roots and are primarily associated with woody plants, aiding in nitrogen and phosphorus uptake (Zhang et al., 2024).

Mycorrhizal associations increase the surface area for absorption, improving the uptake of immobile nutrients like phosphorus and micronutrients such as zinc and copper (Hussain et al., 2024). The extensive hyphal networks of mycorrhizal fungi enhance water absorption, aiding plants during drought conditions. Mycorrhizal plants exhibit increased resistance to soil salinity, heavy metals, and pathogens due to improved nutrient status and induced defense mechanisms (Akter et al., 2024). The hyphae contribute to soil aggregation, enhancing soil structure and aeration. In Scotland, a mycoforestry initiative is cultivating Scots pine seedlings inoculated with ectomycorrhizal fungi to produce edible mushrooms while sequestering carbon, demonstrating the multifaceted benefits of mycorrhizal associations. Research has shown that mycorrhizal fungi play a significant role in carbon sequestration, with root-fungi networks storing more carbon than decomposed plant matter (Pena and Tibbett, 2024). Studies have also indicated that mycorrhizal associations can enhance plant resistance to various stresses, including drought and salinity, by improving nutrient uptake and activating plant defense pathways. Integrating mycorrhizal fungi into agricultural systems can lead to more sustainable practices by reducing the need for chemical fertilizers, improving soil health, and enhancing crop resilience (Sarwade et al., 2024). However, the success of such integration depends on factors like soil conditions, crop type, and the compatibility of fungal species, necessitating further research and tailored application strategies.

4. MICROBIAL ANTAGONISM AND BIOCONTROL: NATURAL DEFENSE AGAINST SOIL-BORNE PATHOGENS

Soil-borne pathogens pose significant challenges to agriculture, leading to crop losses and reduced productivity (Meshram and Adhikari, 2024). Beneficial soil microbes offer a natural means of controlling these pathogens through various antagonistic mechanisms.

Mechanisms of Microbial Biocontrol: Certain microbes produce antibiotics that inhibit the growth of pathogenic organisms. For example, *Bacillus subtilis* strains can produce lipopeptides like mycosubtilin, enhancing their antagonistic activities against fungi (Li et al., 2024). Beneficial microbes compete with pathogens for nutrients and space, limiting pathogen

proliferation. By producing siderophores, beneficial microbes sequester iron, making it less available to pathogens and inhibiting their growth (Hussain et al., 2025). Some microbes produce enzymes that degrade the cell walls of pathogens, leading to their lysis. Beneficial microbes can trigger plant defense mechanisms, enhancing resistance to a broad range of pathogens. *Pseudomonas fluorescens* strains have been shown to protect plant roots against parasitic fungi and produce compounds like 2,4-DAPG with antiphytopathogenic properties. *Bacillus subtilis* BBG100, a strain engineered to overproduce mycosubtilin, demonstrated increased antagonistic activity against several yeasts and pathogenic fungi, leading to improved seed germination and seedling growth (Samal et al., 2025).

Challenges and Considerations: While microbial biocontrol offers a sustainable alternative to chemical pesticides, its effectiveness can be influenced by environmental factors, microbial community dynamics, and the specific pathogen involved (Baba et al., 2025). Therefore, understanding the ecological interactions and optimizing application methods are crucial for successful implementation. In conclusion, leveraging the antagonistic properties of beneficial soil microbes provides a promising strategy for managing soil-borne pathogens, reducing chemical inputs, and promoting plant health in agricultural systems.

5. FUTURE PERSPECTIVES AND SUSTAINABLE INTEGRATION IN AGRICULTURE

The integration of beneficial soil microbes into agricultural practices holds immense potential for promoting plant growth, enhancing stress resilience, and reducing dependency on chemical inputs. As the global population continues to rise and climate change poses increasing challenges to food security, sustainable agricultural practices that harness the power of soil microbes are becoming increasingly vital. Advancements in omics technologies, such as metagenomics, transcriptomics, and proteomics, have deepened our understanding of plant-microbe interactions, enabling the identification of key microbial taxa and functions that contribute to plant health. These insights pave the way for the development of targeted microbial inoculants and biofertilizers tailored to specific crops and environmental conditions.

Moreover, the application of microbial consortia, combining multiple beneficial microbes, has shown promise in enhancing plant growth and resilience under various stress conditions. For instance, the co-inoculation of PGPR and mycorrhizal fungi has been reported to synergistically improve nutrient uptake, water absorption, and disease resistance in plants. However, challenges remain in the widespread adoption of microbial-based solutions in agriculture. Factors such as the variability of field conditions, the stability and shelf-life of microbial products, and regulatory hurdles can impact the effectiveness and acceptance of these solutions. Therefore, ongoing research and collaboration among scientists, industry stakeholders, and policymakers are essential to address these challenges and facilitate the integration of microbial technologies into mainstream agricultural practices. In conclusion, harnessing the potential of soil microbes offers a sustainable pathway to enhance plant growth, improve soil health, and ensure food security in the face of global challenges. Continued investment in research, education, and policy support will be crucial in realizing the full benefits of microbial-based agriculture.

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HARNESSING MOLECULAR MARKERS TO UNRAVEL PATHOGENIC DIVERSITY: IMPLICATIONS FOR PLANT DISEASE MANAGEMENT

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ABSTRACT

Understanding the intricate relationship between molecular markers and pathogenic diversity is pivotal in advancing modern plant pathology and resistance breeding. This mini-review highlights the essential role of molecular markers—such as SSRs, SNPs, and AFLPs—in deciphering the genetic structure, virulence variability, and evolutionary dynamics of plant pathogens. We discuss how these markers have transformed our capacity to characterize pathogen populations, monitor disease outbreaks, and trace pathogen migration. The integration of molecular markers with host resistance gene mapping provides a foundation for durable and targeted disease resistance breeding. Moreover, the application of molecular diagnostics enables early detection and accurate identification of pathogenic strains, facilitating effective disease surveillance. Looking forward, the convergence of omics technologies, precision breeding tools, and bioinformatics is anticipated to revolutionize the way we manage plant diseases, paving the way for pathogen-informed and climate-resilient crop improvement strategies. By exploring this positive relationship, we aim to shed light on the potential of molecular marker technology in enhancing sustainable plant disease management and global food security.

Keywords: Molecular markers, Pathogenic diversity, Plant-pathogen interactions, Resistance breeding, Precision agriculture.

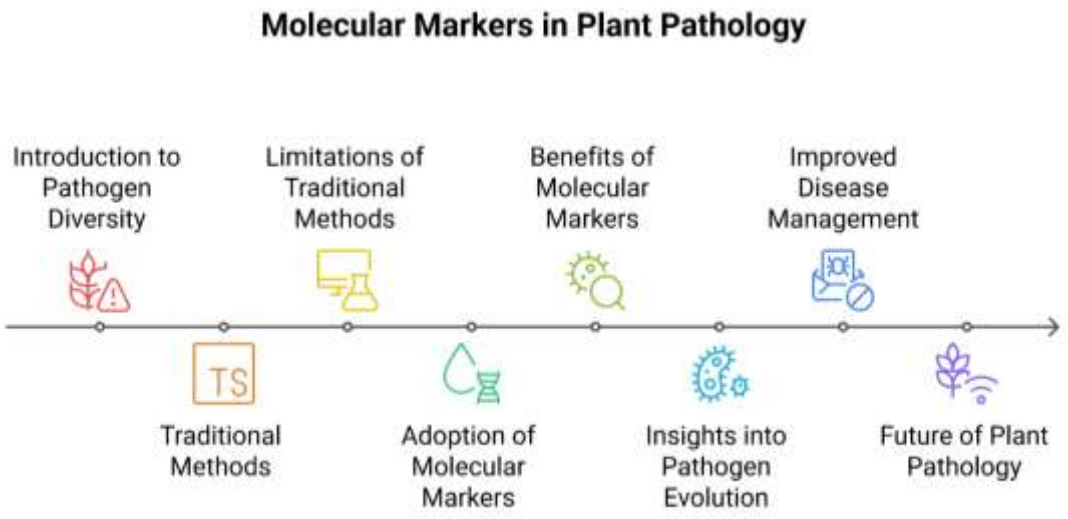
PATOJENİK ÇEŞİTLİLİĞİ ORTAYA ÇIKARMAK İÇİN MOLEKÜLER BELİRTEÇLERDEN YARARLANMA: BİTKİ HASTALIKLARI YÖNETİMİ İÇİN ÇIKARIMLAR

ÖZET

Moleküler belirteçler ile patojenik çeşitlilik arasındaki karmaşık ilişkiyi anlamak, modern bitki patolojisi ve direnç ıslahını ilerletmede çok önemlidir. Bu mini inceleme, SSR'ler, SNP'ler ve AFLP'ler gibi moleküler belirteçlerin bitki patojenlerinin genetik yapısını, virülans değişkenliğini ve evrimsel dinamiklerini çözmedeki temel rolünü vurgulamaktadır. Bu belirteçlerin patojen popülasyonlarını karakterize etme, hastalık salgınlarını izleme ve patojen göçünü izleme kapasitemizi nasıl dönüştürdüğünü tartışıyoruz. Moleküler belirteçlerin konak direnç gen haritalamasıyla bütünleştirilmesi, dayanıklı ve hedefli hastalık direnci ıslahı için bir temel sağlar. Dahası, moleküler tanılamanın uygulanması, patojenik suşların erken tespitini ve doğru bir şekilde tanımlanmasını sağlayarak etkili hastalık gözetimini kolaylaştırır. İleriye bakıldığında, omik teknolojilerinin, hassas ıslah araçlarının ve biyoenformatiğin bir araya gelmesinin, bitki hastalıklarını yönetme şeklimizde devrim yaratması, patojen bilgisine sahip ve iklime dayanıklı ürün geliştirme stratejilerinin önünü açması beklenmektedir. Bu olumlu ilişkiyi araştırarak, sürdürülebilir bitki hastalığı yönetimini ve küresel gıda güvenliğini geliştirmede moleküler belirteç teknolojisinin potansiyeline ışık tutmayı amaçlıyoruz.

Anahtar kelimeler: Moleküler belirteçler, Patojenik çeşitlilik, Bitki-patojen etkileşimleri, Dayanıklı yetiştirme, Hassas tarım.

GRAPHICAL ABSTRACT



1. INTRODUCTION: THE INTERSECTION OF MOLECULAR TOOLS AND PATHOGEN COMPLEXITY

Plant pathogens pose a significant threat to global food security, causing major yield losses across a wide range of crops. Understanding the diversity within and among pathogen populations is crucial for designing effective disease management strategies and ensuring durable host resistance. This diversity termed *pathogenic diversity* encompasses genetic, physiological, and ecological differences that contribute to variation in virulence, host range, and adaptability. Historically, pathogenic diversity was studied through morphological features, pathogenicity tests, and biochemical markers. However, these methods often lacked resolution and reproducibility, especially in species with cryptic morphological features or latent infection phases. The limitations of traditional approaches have driven plant pathologists to adopt molecular markers as more precise and reliable tools for exploring pathogen variability (McDonald and Linde, 2002).

Molecular markers are short DNA sequences with known locations on a genome that show polymorphism between individuals. These markers allow researchers to differentiate pathogen strains, identify race-specific virulence factors, and track pathogen movement across agroecological zones. Unlike phenotypic observations, molecular data are not influenced by environmental factors, making them robust for comparative studies (McDonald and McDermott, 1993). By using DNA-based markers, researchers have gained significant insights into the evolution and spread of virulent pathotypes and the emergence of new pathogen lineages. For instance, studies on rust fungi and *Fusarium* spp. have demonstrated considerable genetic heterogeneity, often correlating with resistance gene breakdown in crops (Zhan et al., 2005). This emphasizes the need to continuously monitor pathogen populations using molecular tools to keep breeding programs ahead of emerging threats (Singh et al., 2016). Moreover, molecular markers have enabled the distinction of closely related but genetically diverse strains that cause similar disease symptoms. This is particularly useful in polyphyletic pathogens like *Colletotrichum*, where taxonomic ambiguity has long hampered disease management strategies (Cannon et al., 2012). As a result, taxonomic revisions guided by molecular data have led to more targeted control practices. The integration of molecular diagnostics into routine pathogen

surveillance has also improved quarantine protocols and pathogen risk assessments. This is crucial in a globalized agriculture system where transboundary spread of pathogens via seed trade or climate-driven expansion is a growing concern (Fisher et al., 2012). Thus, molecular markers not only reveal diversity but also assist in timely intervention. With the rising availability of molecular tools and decreasing costs of DNA sequencing, it is now feasible for many laboratories to use high-resolution markers in their research. Furthermore, the utility of such markers extends beyond research, benefiting disease forecasting systems, resistance gene deployment, and integrated disease management approaches (Cooke et al., 2012).

Overall, molecular markers have become indispensable in plant pathology for dissecting pathogenic diversity, improving our understanding of host-pathogen dynamics, and supporting the development of sustainable crop protection strategies. The future of plant disease management lies in harnessing these tools alongside bioinformatics, omics technologies, and real-time diagnostics (Agrios, 2005; Sharma et al., 2022).

2. MOLECULAR MARKERS: TYPES, PRINCIPLES, AND ADVANCES

Molecular markers are indispensable tools in modern plant pathology for identifying and characterizing pathogen populations at the genetic level. These markers serve as identifiable DNA sequences located at specific positions in the genome, exhibiting polymorphism that enables differentiation among strains, isolates, or species. The evolution of marker technologies over recent decades has significantly enhanced our capacity to investigate pathogen diversity and evolution. The first generation of molecular markers, such as Restriction Fragment Length Polymorphisms (RFLPs), offered relatively stable and co-dominant markers. However, their labor-intensive and time-consuming protocols limited their widespread use. Later, Random Amplified Polymorphic DNA (RAPD) and Inter Simple Sequence Repeats (ISSR) emerged as faster alternatives, although they were dominant and less reproducible (Zietkiewicz et al., 1994). Simple Sequence Repeats (SSRs), also known as microsatellites, are tandem repeats of 1–6 base pairs. They are highly polymorphic, reproducible, and co-dominant, making them ideal for pathogen genotyping. SSRs have been successfully applied in the genetic analysis of several phytopathogenic fungi, such as *Fusarium oxysporum*, *Colletotrichum* spp., and *Magnaporthe oryzae* (Gao et al., 2007; Sharma et al., 2013). Amplified Fragment Length Polymorphisms (AFLPs) offered a higher resolution and greater number of polymorphic markers compared to RAPD and ISSR. Their ability to detect variability in closely related isolates made them useful in population structure studies of pathogens like *Phytophthora infestans* and *Alternaria* spp. (Forster et al., 1996). However, AFLPs are still technically demanding and have now largely been replaced by more advanced technologies. Single Nucleotide Polymorphisms (SNPs) represent the most abundant form of genetic variation in genomes and are ideal for high-throughput genotyping. The development of SNP arrays and genotyping-by-sequencing (GBS) platforms has revolutionized pathogen genetics, enabling detailed mapping of virulence genes, mating types, and population dynamics (Marees et al., 2018). SNP markers have been widely adopted for genome-wide association studies (GWAS) and phylogeographic analyses of fungal and bacterial pathogens.

With the advent of Next-Generation Sequencing (NGS), molecular marker development has become faster, cheaper, and more precise. NGS-based approaches allow for whole-genome resequencing, transcriptome analysis, and detection of novel markers from uncharacterized pathogens. Pathogen genome assemblies now facilitate in silico mining of SSRs, SNPs, and other markers, enhancing the depth of diversity studies (Schmidt et al., 2013; Goodwin et al., 2015). Moreover, molecular markers have expanded from neutral genetic markers to functional

markers that are directly associated with virulence genes or effector loci. This shift allows researchers to not only track genetic variation but also correlate it with specific pathogenic traits. Functional markers provide insight into selection pressures on effector genes and help in understanding host-pathogen co-evolution (Stergiopoulos and de Wit, 2009). High-throughput genotyping technologies, such as DArTseq, TILLING, and CRISPR-based genotyping, are now emerging in phytopathology. These platforms allow simultaneous analysis of thousands of loci across diverse pathogen populations, offering an unprecedented scale of resolution for diversity analysis. The integration of these tools has significantly contributed to constructing linkage maps, identifying QTLs for aggressiveness, and developing molecular diagnostics (Sansaloni et al., 2011).

In addition to genetic markers, epigenetic markers such as methylation-sensitive amplified polymorphisms (MSAPs) are being explored to study pathogen adaptation mechanisms. Such approaches provide insights into how pathogens modulate gene expression to overcome host defenses without permanent genetic changes. This represents a novel frontier in understanding transient but heritable pathogen traits (Rodríguez López and Wilkinson, 2015). Collectively, the rapid evolution of marker technologies from low-throughput PCR-based markers to high-resolution sequencing-based platforms has dramatically advanced our ability to study pathogenic diversity. These innovations provide not only deeper genetic resolution but also faster and more accurate pathogen diagnostics, which are crucial for effective disease surveillance and breeding programs (Linde, 2010; McDonald and Mundt, 2016). As technology progresses, it is expected that marker systems will continue to become more cost-effective, portable, and integrable with decision-support systems. This will facilitate their use in field-level diagnostics, allowing plant pathologists and breeders to make real-time decisions on resistance deployment and disease control strategies. The ongoing convergence of molecular marker science with genomics and bioinformatics heralds a new era in plant disease management.

3. POSITIVE ROLE OF MOLECULAR MARKERS IN ASSESSING PATHOGENIC DIVERSITY

Understanding the genetic diversity of plant pathogens is essential for effective disease control and resistance breeding. Molecular markers play a critical role in accurately assessing this diversity by offering insights into population structure, evolutionary dynamics, gene flow, and virulence mechanisms. These insights directly aid plant pathologists in designing targeted and sustainable disease management strategies. Traditional methods such as morphological characterization and host range studies provide limited resolution and can be influenced by environmental conditions. In contrast, molecular markers offer high specificity and reproducibility, enabling differentiation among closely related strains or pathotypes (McDonald and Linde, 2002). This is particularly important in pathogens with cryptic species complexes, such as *Fusarium oxysporum* or *Colletotrichum gloeosporioides*, where morphological features are insufficient for accurate identification (Fotouhifar et al., 2010). Using markers like SSRs and SNPs, researchers can explore intra- and inter-specific variability with high resolution. For instance, SSR analysis of *Puccinia striiformis f. sp. tritici* revealed multiple clonal lineages responsible for stripe rust outbreaks across continents (Ali et al., 2014). Such findings highlight how marker-based studies can trace pathogen spread and identify emerging virulent strains.

Similarly, studies using AFLP and ISSR markers have demonstrated high genetic variation in *Alternaria solani*, the causal agent of early blight in tomato, indicating the pathogen's adaptive potential under fungicide selection pressure (Rodriguez et al., 2010). This information is vital

for tailoring resistance management strategies and monitoring fungicide resistance development. In fungal pathogens such as *Rhizoctonia solani*, ISSR and RAPD markers have been used to distinguish isolates from various agro-ecological zones, confirming the influence of local environments on pathogen evolution (Lakshman et al., 2014). This regional understanding of pathogen diversity facilitates site-specific recommendations for resistant cultivars and control practices. Molecular markers have also uncovered gene-for-gene interactions by identifying avirulence and effector genes in pathogens. SNP-based genotyping has enabled the discovery of polymorphisms in avirulence loci of *Magnaporthe oryzae*, shedding light on host specificity and resistance gene deployment (Yoshida et al., 2009). These insights help breeders deploy resistance genes more strategically to delay pathogen adaptation. Moreover, molecular markers assist in defining the reproductive strategy of pathogens whether clonal, sexual, or mixed which has significant implications for their evolutionary potential. For example, SSR analysis of *Zymoseptoria tritici* populations revealed frequent recombination, suggesting a high potential for the emergence of new virulent genotypes (Zhan et al., 2003). Understanding such dynamics is critical for developing durable resistance.

In oomycetes such as *Phytophthora infestans*, multilocus SSR analysis has provided global surveillance data to monitor shifts in pathogen lineages and track migrations. These efforts led to the identification of aggressive lineages like EU_13_A2 in Europe, which contributed to increased late blight severity in potato crops (Cooke et al., 2012). This has emphasized the importance of real-time diversity monitoring for disease forecasting and resistance deployment. Markers are also used to analyze mating types and pathogenicity groups in pathogens like *Verticillium dahliae*, where vegetative compatibility and clonal lineages determine virulence. Marker-assisted differentiation of race-specific strains helps in deploying cultivar-specific resistance genes, minimizing crop loss (Jiménez-Díaz et al., 2011). In bacterial pathogens, molecular markers such as rep-PCR and MLSA (Multi-Locus Sequence Analysis) have helped identify diversity among pathovars of *Xanthomonas* and *Pseudomonas*. These studies not only aid in quarantine and surveillance but also enhance our understanding of pathogen ecology (Timilsina et al., 2020). Molecular tools have been pivotal in studying horizontal gene transfer, a major mechanism in pathogen evolution. For instance, the presence of transposable elements or mobile effector genes in *Fusarium graminearum* and their association with virulence was confirmed through marker-assisted sequencing studies (Ma et al., 2010). This adds a new dimension to the understanding of pathogenic variability and potential emergence of novel pathotypes.

Furthermore, studies using molecular markers enable the classification of pathogens into distinct phylogenetic groups or races, which can be correlated with host resistance breakdown. This approach helps define the durability of resistance sources and guides the selection of breeding lines with broad-spectrum resistance (Chen et al., 2009). Pathogen population studies using molecular markers can also indicate bottlenecks, founder effects, or genetic drift, which might influence virulence diversity. Such data is essential for understanding pathogen evolution under changing agricultural practices and climate change scenarios (Milgroom, 2015). In summary, molecular markers provide an accurate, detailed, and scalable approach to evaluate pathogen diversity, enabling more informed decisions in resistance breeding, disease monitoring, and integrated disease management strategies. These tools form the backbone of predictive phytopathology, allowing early detection and response to new or re-emerging threats in agriculture (McDonald and Mundt, 2016).

4. APPLICATIONS OF MARKER-BASED PATHOGEN PROFILING IN RESISTANCE BREEDING

The integration of molecular markers into pathogen profiling has revolutionized resistance breeding by providing plant pathologists and breeders with precise tools to understand the genetic makeup of pathogens and their interaction with host plants. Through these applications, resistance breeding has become more efficient, targeted, and durable. One of the most significant applications is in identifying specific races or pathotypes of a pathogen that threaten particular cultivars. Using molecular markers, distinct pathogen genotypes can be rapidly identified and matched to known virulence patterns, allowing breeders to deploy appropriate resistance genes accordingly (Chen et al., 2013). This race-specific profiling helps in the development of differential host sets and resistance screening programs. For example, the identification of race-specific virulence in *Blumeria graminis* f. sp. *tritici* using SSR markers has allowed breeders to tailor their resistance breeding strategies more effectively by pyramiding multiple resistance (R) genes (Huang et al., 2014). This has improved the durability of resistance in wheat against powdery mildew.

Marker-assisted pathogen diagnostics can also guide resistance gene introgression. In rice, knowledge of *Magnaporthe oryzae* populations through SNP and InDel markers enabled the successful deployment of *Pi9*, *Pi54*, and *Pi2* genes in breeding programs (Singh et al., 2015). These genes were selected based on their effectiveness against prevalent pathogen lineages. Moreover, resistance gene deployment strategies such as gene rotation and mosaic resistance depend heavily on the availability of molecular data on pathogen virulence and diversity. When such information is integrated with Geographic Information Systems (GIS), regional resistance management becomes feasible (Burdon and Thrall, 2008). This approach is critical for managing diseases like rusts and late blight across diverse agro-climatic zones. Genomic insights from pathogen populations also enable breeders to anticipate virulence shifts. For instance, monitoring the evolution of *Phytophthora sojae* races in soybean through marker-based virulence typing has led to more sustainable deployment of *Rps* genes (Yan and Nelson, 2019). This practice ensures resistance is not quickly broken down by evolving pathogen populations.

Molecular markers help breeders screen germplasm collections more effectively by using representative pathogen isolates. Rather than testing against a single isolate, breeders can use marker-defined virulence clusters to ensure broad-spectrum resistance (McDonald and Linde, 2002). This enhances the reliability of resistance screening and cultivar release. Efforts in legumes such as chickpea and lentil have benefitted from marker-based *Ascochyta rabiei* diversity analysis, which provided a foundation for multi-race screening and the development of resistant genotypes (Imtiaz et al., 2015). This has significantly improved disease resistance breeding efficiency in these crops. Another notable application is the identification of pathogen effectors through comparative genomics and molecular marker tagging. Effector profiling of *Leptosphaeria maculans* in canola, for example, helped identify AvrLm genes, which were then matched with host resistance genes to guide breeding efforts (Balesdent et al., 2013). Such precision breeding ensures that resistance is tailored to known pathogen effector repertoires. Markers also aid in resistance durability testing. By artificially inoculating host plants with diverse genotypes of a pathogen identified through molecular analysis, breeders can determine the long-term stability of host resistance under field and controlled conditions (Miedaner and Korzun, 2012). This helps avoid resistance breakdown shortly after cultivar release.

Furthermore, the ability to track pathogen migration and population dynamics via molecular markers helps in forecasting disease risks, guiding breeders to prepare in advance. For instance,

Fusarium oxysporum f. sp. cubense TR4 detection using specific markers has become crucial in banana breeding programs to avoid deploying susceptible cultivars in high-risk areas (Dita et al., 2018). In cereal crops, monitoring *Zymoseptoria tritici* genetic diversity has supported the identification of core virulence determinants and enabled breeders to design resistance gene pyramids based on complementary modes of action (Goodwin et al., 2011). Marker data has also helped in post-release monitoring of resistance efficacy. Marker-based pathogen profiling also facilitates pre-breeding and the development of Near-Isogenic Lines (NILs). These NILs can be used to validate resistance under exposure to characterized pathogen populations, ensuring that newly developed lines carry the desired resistance traits without unwanted linkage drag (Zhang et al., 2017). Pathogen marker data is increasingly being integrated into genome-wide association studies (GWAS) and genomic selection (GS) pipelines, helping to develop cultivars with enhanced and durable resistance. This integration makes breeding more predictive and less dependent on extensive phenotyping (Poland and Nelson, 2011). Ultimately, the synergy between pathogen molecular profiling and resistance breeding leads to the development of cultivars that are not only resistant to existing pathotypes but are also prepared for emerging threats. This is a cornerstone of sustainable plant disease management in the era of climate change and intensive agriculture (Savary et al., 2019).

5. FUTURE PERSPECTIVES AND INTEGRATION OF GENOMICS AND MOLECULAR PATHOLOGY

The convergence of genomics and molecular pathology is set to redefine the future of plant disease management and resistance breeding. With rapid advancements in sequencing technologies and bioinformatics tools, the potential to comprehensively assess pathogen diversity and host-pathogen interactions is now more achievable than ever before. This integration will catalyze a new era of precision agriculture and sustainable crop protection. Future research will focus heavily on the deployment of high-throughput sequencing technologies such as next-generation sequencing (NGS), third-generation long-read platforms like PacBio and Oxford Nanopore, and meta-genomics for detailed characterization of pathogen populations in diverse agro-ecological zones (Massart et al., 2014). These technologies will provide a broader, more accurate picture of pathogenic variability, including rare or cryptic variants that traditional markers may miss.

Pan-genomics and comparative genomics will help capture the full repertoire of genes across entire species and pathotypes, revealing core and accessory genome components critical for virulence, adaptation, and host specificity (Tettelin et al., 2008). For example, identifying dispensable chromosomes or effector islands in fungal pathogens will facilitate more targeted resistance gene development. Transcriptomics and dual RNA-seq approaches are expected to become mainstream for real-time monitoring of host-pathogen interactions. By profiling gene expression during infection, researchers can identify the critical stages at which pathogens deploy effectors and hosts activate immune responses (Westermann et al., 2012). This knowledge will support the design of durable resistance strategies that anticipate pathogen counter-measures. Moreover, advances in genome-wide association studies (GWAS) and genomic selection (GS) will be instrumental in breeding for broad-spectrum resistance. By integrating pathogen marker data with host resistance loci, these tools allow breeders to predict and select elite lines even before full disease screening is conducted (Poland and Rutkoski, 2016). This is particularly beneficial in crops with long breeding cycles such as wheat, rice, and maize. The use of CRISPR-Cas systems and other genome-editing technologies holds immense promise for modifying both host and pathogen genomes to achieve durable disease control.

Host susceptibility genes can be knocked out or modified to block pathogen entry, while pathogens can be studied through targeted gene deletions to identify virulence determinants (Chen et al., 2019). This precise manipulation will advance functional validation and trait enhancement.

Bioinformatic tools are becoming increasingly vital in managing the growing volume of pathogen genomic data. Machine learning and artificial intelligence (AI) models are being developed to predict pathogen evolution, gene-for-gene interactions, and resistance durability (Mahlein, 2016). Predictive modeling will help anticipate disease outbreaks and resistance breakdowns, allowing for proactive breeding and management interventions. In the future, integrated databases linking host genotypes, resistance genes, pathogen genotypes, and geographic occurrence will allow real-time decision-making in breeding programs and disease surveillance. Platforms such as Ensembl Fungi, PHI-base, and OpenWheatBlast are early examples of this trend, offering consolidated resources for breeders and pathologists (Urban et al., 2020). The concept of precision pathology will emerge as a standard practice, wherein disease diagnostics and resistance deployment will be customized to local pathogen populations. Molecular surveillance of pathogen strains in farmers' fields, linked with mobile diagnostics and decision support systems, will guide the application of resistant cultivars and reduce unnecessary pesticide use (Lowe et al., 2017). Furthermore, participatory breeding approaches involving farmers and local stakeholders will gain prominence. These efforts will be enriched by molecular data that ensure resistant cultivars are matched with prevalent local pathogen races, leading to better adoption and greater impact on crop productivity and food security (Ceccarelli and Grando, 2007).

The challenge of emerging and re-emerging pathogens under climate change also underscores the importance of molecular approaches. By monitoring pathogen evolution in response to shifting weather patterns, researchers can adapt resistance strategies accordingly (Bebber, 2015). This is crucial for crops grown in vulnerable or marginal environments. Omics integration (genomics, transcriptomics, proteomics, metabolomics) will offer a systems-level view of host-pathogen dynamics. Such a comprehensive understanding will help discover novel resistance mechanisms, design synthetic resistance pathways, and improve multi-trait breeding pipelines (Gupta et al., 2015). This multidimensional approach will bridge gaps between basic science and applied breeding. Pathogen-informed breeding programs will also prioritize the inclusion of minor and neglected crops, especially those important for regional food security. The availability of molecular marker data for pathogens of these crops will promote genetic improvement, enhancing both yield and resilience (Varshney et al., 2020).

In summary, the integration of molecular markers with advanced genomic tools and precision breeding strategies is critical to addressing the ongoing challenges in plant disease management. By embracing these technologies, plant pathologists and breeders can together develop cultivars that are resilient, productive, and capable of withstanding diverse and evolving pathogenic threats in a changing world.

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INTELLIGENT AGRICULTURE MONITORING AND AUTOMATION SYSTEM

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ABSTRACT

This study developed a Smart Agriculture and Automation System to improve efficiency and sustainability in tomato production while optimizing resource usage. Utilizing components like ESP32, ESP32-CAM, and Raspberry Pi 5, sensor data from temperature, soil moisture, and light sensors were wirelessly transmitted for controlling irrigation, heating, and lighting. Plant development and health were analyzed with YOLOv8-based image processing. The system continuously monitors environmental conditions, evaluates plant health through AI, and reduces manual intervention. The study successfully enhanced water and energy use efficiency, enabled remote monitoring, and improved agricultural productivity, addressing climate and resource management challenges.

Keywords: Smart Agriculture, Automation System, Image Processing, Resource Efficiency

Introduction

Today, global challenges such as population growth and climate change have made it essential to adopt sustainable and efficient methods in agricultural management and production. Traditional agricultural practices often fall short in optimizing resource use and ensuring continuous monitoring of plant health. Limitations in water and energy resources, along with increasing drought risks, have further highlighted the need for intelligent and automated solutions. In this context, the study focuses on the development of a smart agriculture automation system utilizing ESP32, ESP32-CAM, and Raspberry Pi 5, aiming to improve productivity and sustainability in tomato cultivation. By integrating artificial intelligence and image processing technologies, this system enables real-time monitoring of plant development and environmental conditions, providing farmers with more effective tools for decision-making and resource management (Friday Odoh, 2023).

Existing agricultural monitoring and automation systems face significant limitations in maintaining optimal environmental conditions tailored to plant needs. Many lack the capability for continuous and accurate data collection and still rely heavily on manual intervention. This not only lowers agricultural efficiency but also leads to unnecessary consumption of water, energy, and labor. Mismanagement of key parameters such as temperature, light, and soil moisture can directly impact crop yield and sustainability. This study addresses these challenges by proposing a system that combines sensor-based environmental monitoring, AI-powered image analysis, and automated control mechanisms to optimize agricultural processes and improve overall efficiency (Rashed, 2025).

The primary objective of the study is to enhance agricultural productivity by ensuring precise control over environmental variables and efficient use of natural resources. The smart agricultural automation system developed within the study analyzes the maturity and health status of tomato plants using image processing techniques and periodically collected sensor data. Parameters such as soil moisture, temperature, and light intensity are continuously monitored, and corresponding actuators are automatically triggered when necessary. The collected data and analysis results are presented to the user through a web-based interface, allowing remote access and management. By implementing automated irrigation, lighting, and heating systems, the study demonstrates a significant reduction in manual labor while promoting resource efficiency and sustainability. Ultimately, the study supports the digital transformation of agriculture and offers an innovative approach to meeting the demands of modern agricultural production (Naiqian Zhang, 2006).

Materials and Methods

In this study, a smart agricultural automation system was implemented to optimize agricultural processes through sensor-based data collection, artificial intelligence-based image processing, automatic control mechanisms, and a user-friendly web interface. The system was developed and successfully operated through a series of structured steps, beginning with the integration of various hardware components. ESP32-CAM, ESP32, and Raspberry Pi 5 served as the core processing units, while DHT11 temperature and humidity sensors, capacitive soil moisture sensors, and 5mm LDR light sensors collected environmental data. Additional components such as a water pump, LED lighting, fan, carbon heating film, and irrigation channels supported the control mechanisms (Espressif Systems, n.d.).

Sensor data were continuously collected from the greenhouse environment. The capacitive sensor measured soil moisture, the DHT11 sensor monitored ambient temperature, and the LDR sensor evaluated light intensity. These data were transmitted wirelessly to the Raspberry Pi 5

via the ESP32 modules (Raspberry Pi Foundation, n.d.). Simultaneously, the ESP32-CAM captured periodic images of tomato plants, which were then processed using a trained YOLOv8 model running on Raspberry Pi 5. This enabled real-time analysis of plant maturity and health, allowing for early detection of potential issues (ultralytics, n.d.).

Based on the environmental data and image processing outcomes, the system autonomously activated irrigation, heating, lighting, and ventilation when values deviated from predetermined thresholds. The processed information and system status were made accessible to users through a web-based interface, which also allowed for manual control when needed.

In terms of software and theoretical models, Python was used extensively for sensor data processing, control mechanism management, web application deployment, and integration of the AI model. The YOLOv8 algorithm was trained and utilized for evaluating plant health and maturity through visual analysis. The hardware setup included ESP32-CAM, ESP32, Raspberry Pi 5, environmental sensors, and actuators.

The experimental phase of the study began with the construction of a small-scale greenhouse model. Sensors were strategically placed to collect environmental data, and images were captured at regular intervals. All collected data were transmitted to the Raspberry Pi 5, where analysis was conducted, and appropriate actions were triggered automatically. The system's reliability was enhanced through iterative testing and by replacing or adjusting components that were initially incompatible. As a result, a stable, responsive, and efficient smart agriculture system was successfully established.

System Components

Capacitive Soil Moisture Sensor: The capacitive soil moisture sensor (Figure 1), which is more durable than the dual probe soil moisture meter, will measure soil moisture as a long-lasting sensor that prevents resistance wear problems.



Figure 21. Capacitive Soil Moisture Sensor

DHT11 Temperature and Humidity Sensor: This sensor with high sensitivity (Figure 2) will increase efficiency by measuring environmental temperature values. Although the DHT22 sensor is newer and more advanced, the DHT11 sensor was used due to data transmission interruptions.



Figure 22. DHT11 Temperature and Humidity Sensor

LDR Light Sensor: It will help provide the ideal light level for photosynthesis by providing analog output according to the ambient light (Figure 3).



Figure 23. LDR Light Sensor

Raspberry Pi 5: It will be used for artificial intelligence operations and as the main control unit (Figure 4).



Figure 24. Raspberry Pi 5

ESP32 CAM: It will take periodic photographs of tomatoes with its integrated camera and transmit this information wirelessly to Raspberry Pi 5 (Figure 5).



Figure 25. ESP32 CAM

ESP32: ESP32 will collect data from the sensors it is connected to and transmit it wirelessly to Raspberry Pi 5 (Figure 6).



Figure 26. ESP32

Results and Discussion

In this study, a smart agriculture system integrating sensor-based monitoring, artificial intelligence-supported image analysis, and automation technologies was designed, implemented, and tested to enhance agricultural efficiency and sustainability. The system was developed using microcontrollers such as ESP32 and ESP32-CAM for data collection and image capture, with Raspberry Pi 5 serving as the central processing and control unit. Environmental data—including temperature, soil moisture, and light intensity—were continuously collected via DHT11, capacitive soil moisture, and LDR sensors placed in the greenhouse environment. These data were transmitted wirelessly at regular intervals from

ESP32 modules to Raspberry Pi 5 and stored in a local database for analysis. In parallel, images of tomato plants were captured periodically by ESP32-CAM and analyzed using a YOLOv8 model trained to classify tomatoes into maturity stages such as ripe, unripe, and rotten. This enabled both environmental and visual data to be processed in real time, supporting autonomous decision-making and early detection of problems related to plant health.

The implementation of the system followed a structured process divided into several work packages. The hardware installation phase involved integrating all sensors with the ESP32 microcontrollers and connecting actuators such as a water motor, heating film, and lighting units to Raspberry Pi 5. Following successful physical integration, custom firmware was developed for the sensors, and a socket-based WiFi communication protocol was established for reliable data transfer. A Python-based web interface using the Flask framework was designed to provide users with real-time access to sensor readings, system status, and image analysis results. This interface allowed users to remotely monitor temperature, light, soil moisture, and plant maturity levels, as well as to manually intervene when necessary, enhancing both usability and system transparency.

The artificial intelligence component of the system was implemented by preparing a dataset of tomato images representing various maturity and health conditions (Kangwon National University, 2024). This dataset was used to train the YOLOv8 model, which was then deployed on the Raspberry Pi 5. As images were captured by ESP32-CAM, they were transferred wirelessly and processed locally. The model successfully detected and classified tomato stages, enabling the system to automatically activate irrigation, lighting, and heating systems based on both sensor data and visual feedback (Maker Advisor, n.d.).

System performance was evaluated through an extended test period under real greenhouse conditions. During this phase, the stability, accuracy, and responsiveness of the system were monitored. It was observed that the irrigation system was activated only when the soil moisture level dropped below a defined threshold, ensuring efficient water use. Similarly, the lighting system was triggered when light intensity was inadequate, supporting optimal plant growth conditions. The image processing module consistently provided correct classifications of tomato maturity levels, validating the reliability of the YOLOv8 algorithm in the agricultural context. The web interface functioned without error, delivering a clear and accessible representation of all system data and controls.

In conclusion, the developed smart agriculture system demonstrated reliable performance, accurate data collection, and successful integration of image-based plant monitoring with sensor-driven automation. The system not only optimized resource use—particularly water and energy—but also minimized the need for manual labor and enhanced the ability to monitor and manage plant development remotely. These results indicate that the proposed system is scalable and adaptable for broader agricultural applications and can contribute meaningfully to the digital transformation and sustainability of modern agriculture.

Conclusion

The smart greenhouse automation system developed in this study has been successfully implemented, demonstrating the significant role of digitalization and automation in modern agriculture. Key functions such as sensor-based environmental monitoring, plant analysis through image processing, and automatic control of irrigation and lighting were carried out effectively. The sensor data collected for temperature, soil moisture, and light levels were consistent and accurate, and the system responded appropriately based on predefined threshold

values. The image processing analyses conducted using the YOLOv8 model enabled accurate classification of tomato maturity levels and supported the decision-making mechanisms within the system. The web-based interface allowed users to monitor the system in real time, ensuring both technical functionality and user accessibility. The system operated with stability during the test process, provided savings in water and energy use, and allowed for more controlled plant development. The results indicate that the system is not only applicable to small-scale setups but also has the potential to be implemented in larger agricultural environments.

Upon completion of the study, several targets were successfully achieved. Water consumption was reduced through intelligent irrigation control. The need for manual intervention decreased significantly. Environmental parameters in the greenhouse were optimized, leading to increased agricultural productivity. A user-friendly, accessible, and efficient smart agriculture system was established. The system also contributed to sustainable farming practices and supported the digital transformation of agricultural production.

Looking forward, the system can be further enhanced by integrating IoT technologies and big data analytics, making it adaptable to agricultural enterprises of various scales and suitable for different plant species. The YOLOv8 model can be retrained using datasets tailored to specific crops, allowing the system to be used in a wide range of agricultural applications. Mobile application support can be added to improve flexibility and accessibility. Integration with weather APIs would allow the system to incorporate external environmental data into its decision processes. Additionally, renewable energy sources such as solar panels could be used to make the system energy-independent. More advanced features, such as early disease detection through weed or insect identification, could also be integrated into the image processing module to further enhance the system’s capabilities.

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RECRATIONAL LANDSCAPE DESIGN PROJECT OF BARTIN RIVER KANLIIRMAK LOCATION

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ABSTRACT

Bartın City has gained a unique identity in line with its natural, cultural and spatial values throughout the historical process. The Bartın River, from which the city takes its name, has directly influenced both settlement decisions and social and economic life throughout history, and has been a determining factor in the development of the city. In the study, it is aimed to re-function the area located on the Kanlıırmak coastline of the Bartın River with a recreational landscape design while preserving its natural and cultural values. Since the recreation areas along the Yalı in the city are insufficient, a new coastal arrangement proposal was presented on the banks of the Bartın River between the Umut Cafe, one of the landmarks of the city, and the Kemal Samancıoğlu Ethnography Museum within the scope of the project. Seven re-functionalized historical buildings in the area are proposed as an ethnography museum, public library, science center, traditional archery association, fishing association, guesthouse and handicraft course center. The project is shaped by the principles of landscape design, sustainable use of cultural heritage and protection of ecological diversity. This approach aims to both increase the quality of life of the city and preserve the historical texture of Bartın. In the project, evaluations were made for area use planning within the boundaries of the study area and the landscape design project of the area was drawn. AutoCad, Photoshop, Sketchup and Lumion software were used in the drawing, three-dimensional representation and presentation stages of the projects. It is thought that the final result of the project will provide ideas for riverside planning studies in our country and in the cities of the world.

Keywords: Recreation, landscape design, stream, Bartın

BARTIN IRMAĞI KANLIIRMAK MEVKİİ REKRASYONEL PEYZAJ TASARIM PROJESİ

ÖZET

Bartın kenti, tarihsel süreç içerisinde sahip olduğu doğal, kültürel ve mekânsal değerler doğrultusunda özgün bir kimlik kazanmıştır. Kentin adını aldığı Bartın Irmağı, tarih boyunca hem yerleşim kararlarını hem de sosyal ve ekonomik yaşamı doğrudan etkilemiş, kentin gelişiminde belirleyici bir unsur olmuştur. Bu projede Bartın Irmağı'nın Kanlıırmak mevkii kıyı şeridinde yer alan alanın, doğal ve kültürel değerlerini koruyarak rekreasyonel peyzaj tasarımıyla yeniden işlevlendirilmesi hedeflenmiştir. Kentte Yalı boyunca rekreasyon alanları yetersiz kaldığı için, proje kapsamında kentin nirengi noktalarından biri olan Umut kafe ile Kemal Samancıoğlu etnografya müzesi arasında kalan Bartın Irmağı kıyısında yeni bir kıyı düzenleme önerisi sunulmuştur. Alanda yeniden işlevlendirilmiş 7 tarihi yapı; etnografya müzesi, halk kütüphanesi, bilim merkezi, geleneksel okçuluk derneği, balıkçılık derneği, misafirhane ve el sanatları kurs merkezi olarak önerilmiştir. Öneri peyzaj tasarımı, kültürel mirasın sürdürülebilir kullanımı ve ekolojik çeşitliliğin korunması ilkeleriyle şekillenmiştir. Bu yaklaşım, hem kentin yaşam kalitesini artırmayı hem de Bartın'ın tarihi dokusunu yaşatmayı amaçlamaktadır. Projede, çalışma alanı sınırlarında, alan kullanım planlamasına yönelik değerlendirmeler yapılmış ve alanın peyzaj tasarım projesi çizilmiştir. AutoCad, Photoshop, Sketchup ve Lumion yazılımları projelerin çizimi, üç boyutlu gösterimleri ve sunumu aşamalarında kullanılmıştır. Üretilen sonuç projenin ülkemiz ve dünya kentlerinde nehir kenarı düzenleme çalışmalarına fikir vereceği düşünülmektedir.

Anahtar Kelimeler: Rekrasyon, peyzaj tasarımı, akarsu, Bartın

Giriş

Günümüzde kentleşmenin hızla artması, doğal ve kültürel miras alanlarının korunmasını ve kent hayatına dahil edilmesini zorunlu hale getirmiştir. Bu kapsamda sürdürülebilir ve ekolojik kentsel gelişim, yalnızca ekonomik gelişmeyi değil, aynı zamanda ekosistemin korunmasını, kültürel değerlerin devam ettirilmesini ve toplumun yaşam kalitesinin artırılmasını hedeflemelidir (**Erdoğan, 2010;** Çelik, 2011**).** Peyzaj mimarlığı disiplini, bu çok boyutlu hedeflerin tamda orta noktasında yer almaktadır. Özellikle kıyı bölgelerinde, doğal süreçleri ve kültürel değerleri dikkate alan, ekolojik, estetik ve işlevsel çözümler üreterek doğayı temel alan peyzaj planlamaları ve tasarımları geliştirmektedir (Özsüle, 2005).

Peyzaj projeleri sürdürülebilir ve ekolojik kentsel gelişim ile kültürel mirasın korunması arasındaki bağlantıyı sağlayarak, kentlerin daha yaşanabilir ve karakteristik hale gelmesine önemli katkılar sağlar. Doğa tabanlı çözümlerle kıyı bölgelerinde ekolojik koridorların oluşturulması, biyolojik çeşitliliği teşvik eden yeşil altyapı sistemlerinin tasarlanması, doğal süreçlere hassasiyetle yaklaşan kıyı düzenlemelerinin yapılması ve tarihi dokuyu ön planda tutan kamusal alan tasarımları, bu projelerin kapsamındadır (Kaya ve Taylan Susan, 2020). Bu projeler kentlerin doğal ve kültürel değerlerini koruyarak, kentlerde yaşayan halkın refahını artırır ve gelecek nesillere aktarılacak sürdürülebilir kentsel alanların yaratılmasına olanak tanır (Türker ve Gül, 2022).

Kentlerin sürdürülebilir gelişimi, tüm doğal kaynakların akılcı kullanılmasını ve ekolojik dengenin korunmasını hedef alır (Giray ve Yılmaz, 2015). Bu kapsamda, kentlerde yeşil alan sayısının artırılması, biyolojik çeşitliliğin desteklenmesi, su kaynaklarının sürdürülebilir yönetimi, yenilenebilir enerji sistemlerinin entegrasyonu ve çevre dostu ulaşım seçeneklerinin geliştirilmesi gibi uygulamalar önem kazanmaktadır (Kaya ve Taylan Susan, 2020). Ekolojik kentleşme planları, kentlerin çevresel etkilerini azaltırken, kent halkının sağlıklı ve doğayla iç içe bir yaşam sürmelerine fırsat yaratır (Üstün Topal, 2021).

Kültürel değerlerin korunması ve kent hayatına dahil edilmesi ise, kentlerin kendine özgü kimliklerinin muhafaza edilmesi ve gelecek nesillere aktarılması açısından hayati bir önem taşımaktadır. Tarihi yapılar, geleneksel yerleşim dokuları, arkeolojik sit alanları ve kültürel peyzajlar, kentlerin geçmişini yansıtan ve kent hafızasını oluşturan önemli bileşenlerdir (Ertaş ve Sönmez, 2017). Bu mirasın korunması, yalnızca fiziksel yapıların restore edilmesiyle sınırlı kalmamalı, aynı zamanda bu alanların şehirde yaşayan insanlar tarafından kullanılması, anlamlandırılması ve sahiplenilmesi için uygun kamusal alan düzenlemeleri ve kültürel etkinliklerle desteklenmelidir. Kültürel miras alanlarının sürdürülebilir bir bakış açısıyla yeniden değerlendirilmesi, bu alanların ekonomik ve sosyal canlılığını artırırken kentin kültürel çeşitliliğini de korur (Turgut, 2007).

Tarih boyunca yok olmadan varlığını sürdürebilen pek çok yerleşim, genellikle akarsuların kenarlarında kurulmuştur. İnsanlar, zamanla verimliliğini yitiren toprakları terk ederek, ihtiyaçlarını karşılayabilecek yeni su kenarlarına yönelmişlerdir. Akarsuların sağladığı ulaşım kolaylığı, beslenme ve hareket imkânları gibi ekonomik avantajlar, bu su kaynaklarını önemli hale getirmiştir (An, 1994).

Kontrolsüz sanayi ve konut gelişmeleri, akarsu kenarları ve çevresine zarar verebilmekte ya da bu alanların tamamen ortadan kalkmasına yol açabilmektedir. İmar izni olmadan yapılan yapılar, hatalı planlama kararları, akarsu yataklarına atık ve kanalizasyon bırakılması, standartlara uygun olmayan köprü ve menfezler ile doğal bitki örtüsünün yok edilmesi gibi etmenler akarsuların ve çevrelerinin bozulmasına neden olmaktadır (Kılıçaslan, 2004).

Kent içerisinden geçen akarsu yataklarının düzenlenmesi ve temizlenmesiyle birlikte yürütülecek peyzaj projeleri, bu doğal alanların daha yaşanabilir ve kaliteli kentsel mekânlara dönüşmesini mümkün kılmaktadır (Kılıçaslan, 2004).

Akarsu kıyıları, kentsel ekolojik sürekliliği sağlayan doğal sistemler arasında yer alırken, aynı zamanda toplumun sürekli kullanımına açık alanlardır. Bu nedenlerle, kıyı bölgeleri peyzaj planlaması ve tasarımı açısından oldukça büyük bir öneme sahiptir (Arslan ve ark., 2005). Farklı kot farklarına sahip olan akarsu kıyıları, çeşitlilik içeren rekreasyon alanları oluşturmaya elverişlidir. Bu alanlar; yürüyüş ve gezinti yolları, doğayla bütünleşik küçük parklar, piknik alanları, seyir noktaları, balık tutma alanları ile kayık, kano, yelken gibi su aktivitelerine yönelik tesisler, restoran, kafeterya gibi sosyal mekânları içerebilir. Bu tür rekreasyonel kıyı kullanım alanlarına gezinti tekneleri, yürüyüş yolları, bisiklet ve paten yolları gibi çeşitli yollar eklenerek ulaşım desteklenmektedir. Kıyı alanlarının bu şekilde kullanımı, hem kente hem de kent halkına önemli katkılar sağlar. Aynı zamanda bu alanlar eğitim ve kültürel etkinlikler açısından da önemli fırsatlar sunar. İnsanların öğrenirken gezip keşfetmesini sağlayan bu mekânlar, kent yaşamının önemli bir parçası olarak öne çıkar (Simsonds, 1994).

Türkiye'nin Batı Karadeniz Bölgesi'nde yer alan Bartın kenti, tarihsel gelişim sürecinde doğal peyzajı ve kültürel yapılarıyla benzersiz bir kent kimliği kazanmıştır. Bu kimliğin en temel belirleyicilerinden biri olan Bartın Irmağı, antik dönemlerden günümüze kadar bölgenin ekonomik, sosyal ve mekânsal gelişimini yönlendiren bir unsur olmuştur. Bartın Irmağı yalnızca doğal bir su kaynağı değil, aynı zamanda kentin geçmişinde önemli bir yeri olan önemli bir kültürel peyzaj ögesidir (Canik, 2011). Ancak günümüzde bu potansiyelin yeterli seviyede kullanılamadığı, kıyının bazı kesimlerinin zamanla kullanışsız ve atıl hale geldiği görülmektedir. Bu kapsamda, çalışmanın odak noktası olan "Kanlıırmak Mevkii", tarihi dokusu korunmuş olmasına rağmen kentle bütünleşememiş, kullanım alanı sınırlı ve yetersiz bir kıyı alanı niteliğindedir. Alanın mevcut fiziksel durumunun incelenmesi, mekânsal potansiyelinin değerlendirilmesi ve bu doğrultuda kamuya açık yaşam alanı tasarım önerisinin geliştirilmesi, çalışmanın temelini oluşturmaktadır. Söz konusu tasarım, hem alanın doğal ve tarihi değerlerini korumayı hem de halkın aktif kullanabileceği, sürdürülebilir ve çok fonksiyonlu bir kamusal alan oluşturmayı amaçlamaktadır.

Bu proje kapsamında, Umut Kafe ile Kemal Samancıoğlu Etnografya Müzesi arasında kalan kıyı şeridi ele alınmış ve mevcut durumda kullanılmayan yedi adet tarihi yapının yeniden değerlendirilmesi ve kullanılabilir hale getirilmesi amaçlanmıştır. Bu yapılar, Etnografya Müzesi, Halk Kütüphanesi, Bilim Merkezi, Geleneksel Okçuluk Derneği, Balıkçılık Derneği, Misafirhane ve El Sanatları Kurs Merkezi gibi kamusal ve kültürel kullanımlarla yeniden yapılandırılarak kent yaşamına kazandırılmıştır. Bu yaklaşım, şehirde yaşayan halkın bu alanla olan bağını güçlendirmeyi, kent kimliğini pekiştirmeyi ve kültürel sürekliliğin sağlanmasına katkıda bulunmayı amaçlamaktadır. Tarihi yapıların korunarak yeni işlevlerle donatılması, hem kültürel mirasın yaşatılmasına olanak tanımakta hem de bu yapıların kent ekonomisine ve sosyal yaşamına aktif katılımlarını sağlamaktadır. Proje Bartın Irmağı kıyısının kent için çekim merkezi haline gelmesine ve kentsel yaşam kalitesinin artırılmasına önemli bir katkı sunmayı hedeflemektedir.

Materyal

Bartın şehir merkezinde, Bartın Irmağı'nın Kanlıırmak Mevkii kıyı şeridinde yer alan ve mevcut durumda atıl durumda bulunan alan çalışma alanını oluşturmaktadır (Şekil 1).

Bartın Kenti, adını antik dönemde "suların tanrısı" olarak bilinen Parthenios'tan almıştır. Mitolojik anlam taşıyan Bartın Çayı, kentin isim kaynağı olarak kabul edilir. Bartın ve

çevresinde ilk yerleşimlerin M.Ö. 14. yüzyıla kadar uzandığı bilinmektedir (Anonim, 2001). Türkiye İstatistik Kurumu'nun 2025 yılı verilerine göre, kentin nüfusu 185.368 kişidir. Bu nüfusun 90.419'u erkek, 94.949'u ise kadındır; oranlar sırasıyla %49.71 erkek ve %50.29 kadın şeklindedir.

Tarihsel açıdan bakıldığında, Bartın Çayı bölgedeki ticaret faaliyetlerinin gelişmesinde kritik bir rol oynamıştır. Bu suyolu üzerinden çeşitli ürünlerin limanlara taşınması sağlanmıştır. Bu sebeple Bartın Çayı, M.Ö. 11-10. yüzyıllarda Fenikeliler ve ardından Kayralı ile Megaralı denizci tüccarlar tarafından da bilinmekteydi. Ünlü seyyah Evliya Çelebi, Seyahatnamesi'nde Bartın Çayı'nı "azametli bir nehir" olarak tanımlamış ve üzerinde buğday ile mısır yüklü gemilerin hareket ettiğini belirtmiştir (Erkin, 1978). Bartın'daki gemi üretimi ise yaklaşık dört asırlık geçmişe sahiptir ve bu faaliyetlerin 1950'li yıllara kadar sürdüğü kaydedilmektedir (Anonim, 2005).



Şekil 1. Çalışma alanı

Bartın Çayı, sadece taşımacılık yönünden değil, aynı zamanda kentsel ölçekte rekreatif kullanımlar açısından da önemli bir potansiyele sahiptir. Ancak günümüze kadar yalnızca birkaç park ve piknik alanı dışında rekreasyonel yatırımlar yapılmamıştır.

Yöntem

Çalışmada alanın topografik yapısı, bitki örtüsü, zemin yapısı, kıyı özellikleri, mevcut yollar ve kullanım durumları yerinde gözlemlenmiş ve mevcut planlar üzerinden değerlendirilerek mevcut durum analiz edilmiştir. Ayrıca, proje alanı sınırlarında yer alan ve yeniden işlevlendirilmesi düşünülen tarihi yapıların mimari özellikleri, mevcut durumları ve yeniden kullanım potansiyelleri detaylı olarak incelenmiştir. Bu incelemelerde plan özellikleri, cephe özellikleri, yapı malzemeleri ve yapılardaki deformasyonlar dikkate alınmıştır.

Çalışma süresince, alanın mevcut ve potansiyel kullanıcı profili (yerel halk, turistler, tematik gruplar vb.) gözleme dayalı yöntemlerle analiz edilmiş, ayrıca alanın tarihi geçmişi, kültürel değeri ve kent hafızasındaki yeri literatür taramasıyla değerlendirilmiştir.

Tasarım sürecinde, elde edilen tüm veriler literatür taramaları ile birleştirilerek, alanın doğal peyzajı ve tarihi dokusunu korumayı hedefleyen, kullanıcı ihtiyaçlarına yönelik, sürdürülebilir ve çok fonksiyonlu bir kamusal yaşam alanı oluşturulması düşünülmüştür. Bu kapsamda; sürdürülebilirlik, kentte yaşayan halkın katılımı, estetik bütünlük, sosyal işlevsellik ve ekolojik bütünlük ilkeleri tasarım sürecinin temel dayanaklarını oluşturmuştur. Projenin planlama, tasarım ve sunum aşamalarında AutoCAD, SketchUp, Lumion ve Photoshop gibi dijital yazılımlar kullanılmıştır.

Peyzaj Tasarım Projesi

Çalışma alanının fiziksel çevre analizleri, ırmağın kent için önemli doğal ve görsel kaynak olmasına rağmen kıyı şeridinin bazı kısımlarından yeterince faydalanılmadığını ortaya koymuştur. Mevcut bitki örtüsünün yer yer seyrek ve bakımsız olduğu, zemin özelliklerinin kıyı boyunca değişkenlik gösterdiği ve mevcut yolların yaya ve bisiklet kullanımına tam olarak uygun olmadığı tespit edilmiştir. Işık ve gölge analizleri, özellikle yaz aylarında bazı bölgelerde aşırı güneşlenme potansiyeli olduğunu göstermiş, bu durum gölgelendirme elemanlarının yer seçiminde dikkat edilmesi gerektiğini ortaya koymuştur.

Yapılan incelemelerde yedi adet tarihi yapının farklı mimari özelliklere ve farklı seviyelerde yıpranmalara sahip olduğu görülmüştür. Birkaç yapıda mimari detaylar büyük ölçüde korunmuşken, bazılarında önemli ölçüde deformasyon ve tahribat gözlemlenmiştir. Yapıların potansiyellerine göre yeniden kullanılabilirlikleri, mimari karakterleri, büyüklükleri ve konumları dikkate alınarak belirlenmiştir. Bu kapsamda, Etnografya Müzesi ve Halk Kütüphanesi gibi kültürel fonksiyonların yanı sıra, Bilim Merkezi, Geleneksel Okçuluk Derneği ve Balıkçılık Derneği gibi farklı ilgi alanlarına yönelik sosyal ve kültürel mekânlar önerilmiştir. Misafirhane ve El Sanatları Kurs Merkezi gibi fonksiyonlarla alan turizme katkı sağlayacak şekilde yeniden değerlendirilmiştir.

Kullanıcı profili değerlendirmeleri (gözlemler yoluyla elde edilen ön bilgiler), alanın mevcut durumda sınırlı sayıda kişi tarafından ve genellikle dinlenme ve kısa süreli geçiş amaçlı kullanıldığını göstermiştir. Potansiyel kullanıcı kitlesinin ise yerel halkın farklı yaş ve ilgi gruplarından, öğrenciler, sanatseverler ve turistlerden oluşabileceği öngörülmektedir. Bu potansiyel kullanıcıların ihtiyaçları arasında güvenli ve erişilebilir yaya ve bisiklet yolları, oturma ve dinlenme alanları, kültürel ve sosyal etkinliklere katılım imkânları ile doğayla iç içe vakit geçirebilecekleri yeşil alanlar bulunmaktadır.

Kültürel ve tarihi değer analizleri, Bartın Irmağı ve kıyısındaki yapıların kentin tarihi ve kültürel kimliğinde önemli bir yere sahip olduğunu ortaya koymuştur. Irmağın antik dönemlerden günümüze kadar var olduğu, bölgenin ekonomisine ve sosyal yaşamına yön veren bir unsur

olduğu ve kıyısındaki tarihi yapıların kentin geçmişine şahit olduğu belirlenmiştir. Bu kapsamda kültürel mirasın korunması ve gelecek nesillere aktarılması gerekliliği vurgulanmıştır. Mevcut plan ve harita verileri, çalışma alanının büyük ölçüde kamusal kullanıma bırakıldığını göstermektedir. İmar planları, alanda rekreasyon alanı olarak düzenlemeler yapılmasına olanak tanımaktadır.

Çalışmada hem kullanıcı ihtiyaçları hem de ekolojik ve tarihi dokular dikkate alınarak çok yönlü tasarım kararları alınmıştır. Bu kapsamda geliştirilen temel öneri ve tasarım kararları şu şekilde özetlenebilir:

Tarihi Yapıların Yeniden Düzenlenmesi: Alanda yer alan 7 adet tescilli yapı, halk kütüphanesi, etnografya müzesi, bilim merkezi, geleneksel okçuluk derneği, balıkçılık derneği, el sanatları kurs merkezi ve misafirhane gibi işlevlerle yeniden değerlendirilerek mevcut kimlik korunmuştur. Bu sayede kültürel miras korunmuş ve alanın kullanım kapasitesi artırılmıştır (Şekil 2, Şekil 6).



Şekil 2. Restore edilen yapılar ve sokak ilişkisi

Kıyı Şeridi Düzenlemeleri: Irmak kenarına kesintisiz yürüyüş ve bisiklet yolları entegre edilerek aktif ulaşım teşvik edilmiştir. Doğal eğimlerden yararlanarak seyir terasları ve dinlenme alanları oluşturulmuş, bu noktalarla manzara bütünleşik şekilde değerlendirilmiştir (Şekil 3).

Ekolojik ve Yeşil Altyapı Yaklaşımı: Yerli bitki türlerinden oluşan peyzaj alanlarıyla biyolojik çeşitlilik desteklenmiş, geçirgen yüzeyler ve yağmur bahçeleri sayesinde suyun yerinde yönetimi hedeflenmiştir. Ayrıca kıyı ekosisteminin sürekliliğinin sağlanması ve ekolojik koridor oluşumunun desteklenmesi düşünülmüştür (Şekil 4).



Şekil 3. Irmak üzeri yürüyüş promenatı



Şekil 4. Yol ağaçlandırması

Gölgelendirme Alanları: Özellikle yaz mevsiminde oluşan aşırı güneşlenme durumlarına karşı gölgelik yapılar, doğal ağaç gölgeleri ve pergola sistemleri önerilmiş, böylece alanda konforlu kullanım şartları oluşturulmuştur.

Toplumsal ve Kültürel Etkinlik Alanları: Açık hava gösteri alanları, küçük sergi platformları ve tematik oyun alanları gibi sosyal donatılarla her yaştan kullanıcıya hitap eden bir mekânsal tasarım geliştirilmiştir (Şekil 5).

Ulaşım ve Erişilebilirlik: Tüm alan engelsiz tasarım ilkeleri doğrultusunda ele alınmış, rampalar, yönlendirme tabelaları ve uygun zemin kaplamalarıyla engelli vatandaşların da kolaylıkla erişebilecekleri hale getirilmiştir (Şekil 7).

Bu tasarım kararları, Bartın Irmağı'nın kıyı karakterine uygun, sürdürülebilir ve çok fonksiyonlu bir toplumsal alan oluşturmayı hedeflemektedir.



Şekil 5. Irmak kenarı çeşitli aktiviteler



Şekil 6. Yeniden işlevlendirilen alanlar ve tasarım noktaları



Şekil 7. Irmak kenarında evrensel tasarım ilkelerine uygun yaya yolu

Sonuç

Elde edilen veriler Bartın Irmağı kıyısının taşıdığı önemli potansiyelin yeterince açığa çıkarılamadığını net bir şekilde ortaya koymaktadır. Kıyı şeridindeki kullanılamaz durumdaki tarihi yapılar ve bakımsız yeşil alanlar, kentin doğal ve kültürel zenginliklerinin gerektiği kadar değerlendirilmediğini göstermiştir. Bu durum, sürdürülebilir kentleşmeye uymayan bir durumdur.

Yapılan kapsamlı analizler, çalışma alanının yeniden çok yönlü bir toplumsal yaşam merkezine dönüştürülmesinin mümkün olduğunu göstermektedir. Tarihi yapıların kültürel ve sosyal amaçlarla yeniden kullanılır hale getirilmesi, hem kentin kültürel mirasının korunmasını sağlayacak hem de kentte yaşayanlar ve ziyaretçiler için yeni cazibe noktaları yaratacaktır. Önerilen kullanımlar, kullanıcıların beklentileriyle uyumlu olup, alanın farklı ilgi grupları tarafından aktif halde kullanımını teşvik edecektir. Tasarım sürecinde sürdürülebilirlik ilkelerinin temel alınması, alanın uzun vadeli başarısını güvence altına alacaktır. Ekolojik tasarım yaklaşımlarıyla doğal süreçlere saygılı çözümlerin geliştirilmesi, yerel bitki türlerinin seçimi ve doğal malzemelerin kullanımı, alanın çevresel etkilerini azaltarak ekolojik dengeye katkıda bulunacaktır.

Alanın fiziksel, kültürel ve mekânsal verileri incelenerek geliştirilen tasarım; sürdürülebilirlik, tarihi dokunun korunması ve kent yaşamına uyumlu hale getirilmesi gibi ilkeler doğrultusunda şekillendirilmiştir. Tarihi binaların yeniden kullanıma kazandırılması, hem kültürel devamlılığa katkı sağlamış hem de halkın bu alanla olan bağlarını güçlendirmiştir. Proje ile yalnızca fiziksel bir dönüşüm değil, aynı zamanda kent kimliğine değer katan bir sosyal ve kültürel etkileşim alanı yaratılmıştır. Doğal peyzajın sürdürülebilir kullanımı, biyolojik çeşitliliğin desteklenmesi ve su kenarı alanlarının toplumsal hayata entegrasyonu açısından bu proje örnek teşkil etmektedir. Geliştirilen tasarım fikrinin, Bartın başta olmak üzere benzer özelliklere sahip nehir kenarına kurulmuş kentlerde de uygulanabilecek bir model oluşturması beklenmektedir.

Teşekkür

Çalışmada desteğini gördüğümüz Lütfi AĞIRTAŞ'a teşekkür ederiz.

Kaynaklar

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LANDSCAPE DESIGN PROJECT OF KÜÇÜKÇEKMECE BALIKÇI ISLAND PARK

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ABSTRACT

In today's cities, where urban life is intense, the need for open green spaces that support social interaction, preserve the natural balance and have aesthetic qualities is increasing. Landscape design projects carried out in this direction not only increase environmental quality, but also positively affect social welfare and local quality of life. In the study, the Balıkçı Island Park, located within the borders of Fatih Neighborhood of Küçükçekmece District of Istanbul Province and on the coast of the Marmara Sea, was selected as the study area. Although the area currently stands out with its marina function, it is inadequate in terms of landscaping and is used below its potential. In the study, a landscape design project proposal was presented for the area. In the project, the study area was divided into various functional areas such as children's playground, recreation area, concert area, rest area, cafeteria area. Thus, spatial solutions that appeal to different age and user groups were developed in the project. The aim of the design is to provide the user with an aesthetic, functional and healthy public space while preserving the existing potential of the area. An enriched use of the area is proposed with viewing points, green corridors, walking paths, seating areas and plant design elements. 3D modeling of the area was done using AutoCAD, SketchUp, Photoshop and Lumion programs. The visual and usage integrity of the area was checked with the project and models. Thus, the applicability of the project was supported. This project aims to increase the visual, functional and environmental quality of the area, contribute to the social life of the local people and ensure sustainable coastal use. The project will be an example for similar areas.

Keywords: Landscape design, coastal arrangement, recreation, urban open space, Küçükçekmece (Istanbul)

KÜÇÜKÇEKMECE BALIKÇI ADASI PARKI PEYZAJ TASARIM PROJESİ

ÖZET

Kentsel yaşamın yoğunlaştığı günümüz şehirlerinde, sosyal etkileşimi destekleyen, doğal dengeyi koruyan ve estetik nitelikler taşıyan açık yeşil alanlara duyulan ihtiyaç giderek artmaktadır. Bu doğrultuda gerçekleştirilen peyzaj tasarım projeleri, yalnızca çevresel kaliteyi yükseltmekle kalmayıp, aynı zamanda sosyal refahı ve yerel yaşam kalitesini de olumlu yönde etkilemektedir. Bu çalışmada, İstanbul İli Küçükçekmece İlçesi Fatih Mahallesi sınırları içerisinde yer alan ve Marmara Denizi'ne kıyısı bulunan Balıkçı Adası parkı, çalışma alanı olarak seçilmiştir. Alan, mevcut durumda marina işleviyle öne çıkmakla birlikte, çevre düzenlemesi yönünden yetersiz kalmakta ve potansiyelinin altında kullanılmaktadır. Çalışmada alan için peyzaj tasarım proje önerisi sunulmuştur. Projede çalışma alanı; çocuk oyun alanı, mesire alanı, konser alanı, dinlenme alanı, kafeterya alanı gibi çeşitli işlevsel bölgelere ayrılmıştır. Böylece projede farklı yaş ve kullanıcı gruplarına hitap eden mekânsal çözümler geliştirilmiştir. Tasarımın amacı, alanın mevcut potansiyelini koruyarak kullanıcıya estetik, fonksiyonel ve sağlıklı bir kamusal mekân sunmaktır. Alanda seyir noktaları, yeşil koridorlar, yürüyüş yolları, oturma alanları ve bitkisel tasarım ögeleriyle zenginleştirilmiş bir kullanım önerilmiştir. Tasarım sürecinde kullanılan AutoCAD, SketchUp, Photoshop ve Lumion programları aracılığıyla alanın 3D modellemeleri yapılmıştır. Proje ve modellerle alanın görsel ve kullanım bütünlüğü kontrol edilmiş ve projenin uygulanabilirliği desteklenmiştir. Hazırlanan bu proje ile alanın görsel, işlevsel ve çevresel kalitesinin artırılması, yerel halkın sosyal yaşamına katkıda bulunulması ve sürdürülebilir kıyı kullanımının sağlanması hedeflenmektedir. Proje benzer alanlar için örnek olacaktır.

Anahtar Kelimeler: Peyzaj tasarımı, kıyı düzenlemesi, rekreasyon, kentsel açık alan, Küçükçekmece (İstanbul)

Giriş

Günümüzde kentlerde yaşanan hızlı kentleşme süreci, yapılaşmanın yoğunluk kazanmasına, doğal kaynakların ve yeşil alanların ise giderek azalmasına neden olmaktadır. Bu değişim fiziksel çevreyle birlikte bireylerin yaşam kalitesini, kentle ve doğayla kurdukları ilişkileri de etkilemektedir. Yapılaşma sürecinin artması ve beraberinde doğal unsurların azalması kentte yaşayan bireylerin fiziksel ve ruhsal sağlığını destekleyen nitelikli açık yeşil alanlara duyulan ihtiyacı daha da belirgin hâle getirmiştir. Yeşil alanlar, kentsel doku içerisinde mimari yapılar dışındaki açıklıkları, kitlesel ve parçalar halindeki yeşil ögeleri ve su yüzeylerini barındıran, kentin gelişimini kontrol altında tutan, birleştirici ve ayırıcı işlevler üstlenen, kent genelinde bütünlüğü sağlayan ve tüm bunların dışında varlıkları gereği kente başta ekolojik, estetik, rekreasyonel ve ekonomik olmak üzere birtakım yararlar sağlayan sistemler bütünüdür (Ortaçeşme vd., 2020). Rakhshandehroo, ve Yusof (2014)'e göre, kentsel açık yeşil alanlar, doğal ya da yarı doğal ekosistemlerin insan etkisiyle dönüştüğü kentsel alanlardır. Bu kapsamda, kentsel açık yeşil alanların; kent insanının dinlenme, sosyalleşme, doğayla etkileşim kurma ve stresle başa çıkma gibi çok yönlü ihtiyaçlarına yanıt veren kamusal mekânlar olarak önemi artmaktadır.

Kavramsal olarak kıyı alanları ise, kara ile suyun birleştiği yer, karanın su boyunca uzanan kısmı (Pala, 1975; Doğan, 2008), deniz, göl, akarsu gibi her türlü doğal su kütlesini çevreleyen kara parçasıdır (Akbaba, 2010; Muhacir ve Özalp, 2018). Kıyıların, sahip olduğu doğal ve kültürel kaynak değerleri, iklim, jeoloji, hidroloji, flora ve fauna gibi çok sayıda etkene bağlı olarak değişiklik ve çeşitlilik gösterse de, bu özellikleri hem ekolojik hem de kültürel açıdan önemli peyzaj alanları arasında yer almalarını sağlamaktadır. Bununla birlikte, hava, su ve karanın etkileşim altında bulunduğu ve doğal kaynakların zenginliği ile dikkat çeken kıyılar, bu özellikleri nedeniyle her zaman yoğun kullanıma maruz kalmakta ve bu yoğun kullanım, kıyı ekosistemindeki hassas denge üzerinde olumsuz sonuçlara yol açabilmektedir (Garipağaoğlu vd., 2014; Muhacir ve Özalp, 2018). Bu bağlamda kıyıların sahip olduğu morfolojik özellikler, kıyıya, doğal ve görsel özellikler katarken aynı zamanda rekreasyonel açıdan değerlendirilebilecek, kaynağı ve sunduğu aktivite çeşitliliği sayesinde geniş kitlelere hitap edebilecek mekânların oluşumuna da olanak sağlamaktadır (Özgüç, 2011; Pekpak, 2012).

Kıyı alanları, kentsel açık alanlar içerisinde doğal ve görsel özelliği ile birlikte, sunduğu aktivite çeşitliliği nedeniyle de peyzaj çalışmalarında özel bir yer tutar. Kıyıları işlevlendirerek halkın kullanımına kazandırmak için yapılan peyzaj tasarım projeleri bu anlamda önemli rol üstlenir. Bu alanlarda yapılacak peyzaj tasarımları yalnız estetik yönden değil aynı zamanda sosyal bütünleşme, sürdürülebilirlik, ekolojik denge ve kente değer katma gibi birçok farklı amacı içinde barındıran bir süreçtir. Bu kapsamda yapılacak peyzaj tasarım projeleri, kent-kıyı etkileşimini güçlendirme ve kentin sosyal dokusunu canlandırma potansiyeline sahiptir.

Bu çalışma, İstanbul İli Küçükçekmece İlçesi Fatih Mahallesi'nde yer alan ve mevcutta sınırlı kullanımı olan bir marina alanından, çok işlevli bir kamusal açık ve yeşil alana dönüşümü hedeflemektedir. Peyzaj tasarımında gökkuşağı teması esas alınarak, renklerin dinamizmiyle görsel zenginlik yaratılmakta, planlanan çocuk oyun alanları, piknik ve mesire alanları, açık hava etkinlik ve konser alanları, yürüyüş yolları ve sosyal toplanma mekânları ile de yalnızca fiziksel bir dönüşüm değil, aynı zamanda sosyal ve psikolojik olarak kent insanına fayda sağlayan, sürdürülebilir ve kapsayıcı bir kamusal alan önerisi ortaya koymaktadır. Böylelikle proje; kent içi yaşam kalitesini artıran, sosyal bütünleşmeyi teşvik eden ve doğayla kurulan bağı güçlendiren bir peyzaj tasarımı örneği sunmaktadır.

Materyal-Yöntem

Çalışma alanı, İstanbul İli Küçükçekmece İlçesi sınırları içerisinde yer alan Fatih Mahallesi'nde, Küçükçekmece Gölü kıyısındaki Balıkçı Adası ve çevresindeki kıyı alanını kapsamaktadır. Çalışmada öncelikle konuya ve çalışma alanına ilişkin literatür taraması yapılmış, çeşitli kurum ve kuruluşlardan elde edilen bilgiler bilgisayar ortamına aktarılmıştır. Daha sonra çalışma alanında yapılan arazi çalışması ile alandaki sorunlar tespit edilmiş ve ihtiyaçlar belirlenmiştir. Sörvey aşamasından sonra alanın mevcut durumu ve sahip olduğu potansiyeller değerlendirilerek konsept belirlenmiştir. Konsepte göre alan kullanım kararları alınarak tasarım ilkeleri belirlenmiştir. Daha sonra tüm veriler ışığında çalışma alanına ait rekreasyonel peyzaj tasarım projesi geliştirilmiştir. Proje alanı, rekreatif değerleri ve doğal peyzajla bütünleşen konumu sayesinde kent insanına doğayla buluşma imkânı sunan çok işlevli bir kamusal alan olarak kurgulanmıştır. Projelerin çizimi, görselleştirilmesi ve sunumunda AutoCAD, SketchUp, Photoshop ve Lumion programları kullanılmıştır.

Araştırma Bulguları

Çalışma Alanı Doğal ve Kültürel Peyzaj Analizi

Küçükçekmece İlçesi; 40° kuzey enlemi ve 28° doğu boylamı arasında yer almaktadır. Sahil uzunluğu 7 km, il merkezine uzaklığı ise 23 km.dir. İlçe Avrupa yakasında, Çatalca yarımadasının güneydoğusunda yer almaktadır. Batısında Avcılar ve Çatalca, kuzeyinde Gaziosmanpaşa, doğusunda Esenler, Bağcılar ve Bahçelievler güneyinde ise Bakırköy ilçeleri yer almaktadır. Küçükçekmece İlçesi; tarih boyunca İstanbul-Avrupa ana ulaşım aksları üzerinde yer almıştır. İkitelli ve İstanbul arasında ulaşım imkanlarını arttıran TEM otoyolu ilçeden geçmektedir. Sirkeci Halkalı arasında çalışan bir banliyö tren hattı bulunmaktadır. Ayrıca İstanbul'un uluslararası havalimanı olan Atatürk hava limanı da bu ilçede yer almaktadır. Küçükçekmece geniş düzlükler halinde az engebeli bir alana yayılmıştır. Deniz ve göl kıyılarından içerilere doğru girildikçe yükseklik artar. Küçükçekmece Gölü morfolojik (biçim) yapısı nedeniyle tam ve tipik bir lagün gölüdür. Dünyada ender oluşan lagün göllerinden birisidir ve bir doğa harikasıdır. Sahil uzunluğu 7 km'dir (Ertürk, 2011) (Şekil 1, 2).

Küçükçekmece'nin Osmanlı İmparatorluğu'na katılması, Fatih Sultan Mehmet'in İstanbul'u fethinden sonraki dönemlerde olmuştur. Eskiden Küçükçekmece denildiğinde sayfiye yeri akla gelmekteydi. Denizle bağlantısı olan kanalın demiryolu kısmında özellikle yazın sıkça kullanılan mesire yerleri vardı. 1951'de Sirkeci-Halkalı tren yolunun ve Londra yolunun (bugünkü adı ile E-5 karayolu) açılması ilçenin gelişmesi açısından büyük öneme sahiptir. Bölge'de yoğun nüfus artışı 1950'lerde başlamıştır. İlçede Çeşme, Garip Dede türbesi, kibrit fabrikası, Mimar Sinan köprüsü önemli simgeler olarak bilinmektedir. Kıyı parkı, ilçe meydanı en çok gelinen odak noktaları olup, gölün Kanarya tarafındaki çamlık alan mahalle sakinleri tarafından mesire yeri olarak kullanılmaktadır (Ertürk, 2011).

Balıkçı Adası Parkı Küçükçekmece İlçesi Fatih Mahallesi'nde, 40.988850 enlem ve 28.770658 boylamda yer alır. Balıkçı Parkı Adası rakımı 2 metredir. Toplam yüzölçümü 13.500 m²'dir.



Şekil 2. Çalışma alanı ve çevresi (Google Earth, 2025).



Şekil 3. Balıkçı Adası parkının mevcut konumu ve çevre ilişkisi (Harita Map, 2025)

Alan, mevcut durumda sınırlı marina kullanımı dışında büyük ölçüde âtıl durumdadır. Kıyı şeridi, göl ekosistemiyle bütünleşen doğal potansiyeli ve kentsel erişilebilirliği yüksek bir konumda yer alması bakımından önemli peyzaj dönüşüm potansiyeline sahiptir (Şekil 3, 4).



Şekil 3. Balıkçı Adası parkı mevcut durumundan görünüm



Şekil 4. Mevcut çocuk oyun alanından bir görünüm

Öneri Peyzaj Tasarım Projesi

Yapılan alan analizleri, kullanıcı ihtiyaçları ve kentsel bağlam çerçevesinde, Balıkçı Adası çevresine yönelik peyzaj tasarımında; kıyının doğal karakteri korunarak sosyal, rekreatif ve ekolojik değerlerin bütüncül bir yaklaşımla yeniden işlevlendirildiği bir proje üretilmiştir.

Peyzaj tasarım projesinde alınan ana plan kararları;

- Kıyı boyunca süreklilik taşıyan bir yeşil koridor oluşturularak, farklı yaş ve kullanıcı gruplarına hizmet eden çok işlevli alanlar oluşturulmuştur.
- Alandaki âtıl ve niteliksiz boşluklar işlevlendirilerek, kullanıcıların aktif olarak zaman geçirebileceği açık alanlara dönüştürülmüştür.
- Doğal topografya ve ekolojik yapı korunarak, kıyıya özgü bitki türleriyle peyzaj bütünlüğü sağlanmış; bu doğrultuda doğal yaşama uygun, düşük bakım gerektiren bitkilendirme tercih edilmiştir.
- Gökkuşağı teması ile mekânsal çeşitlilik artırılmış; renk kodlu zonlama sayesinde alan, estetik ve deneyimsel bir kamusal mekâna dönüştürülmüştür.
- Yaya ve bisiklet yolları ile erişilebilir ve sağlıklı ulaşım imkânı sunulmuş; engelli bireyler için engelsiz tasarım ilkelerine uygun geçişler planlanmıştır.
- Çocuk oyun alanı, konser sahnesi, mesire alanı gibi fonksiyonlarla sosyal etkileşim desteklenmiş; farklı kullanıcı profillerine hitap eden alanlar tasarlanmıştır.
- Ekolojik sürdürülebilirlik ilkeleri doğrultusunda, geçirgen zemin kaplamaları kullanılmıştır.
- Kıyının kamusal bellekte yer edinmesi hedeflenerek; kültürel, doğal ve sosyal bağlamı yansıtan bir peyzaj dili benimsenmiştir.



Şekil 5. Çalışma alanı kıyı yürüyüş bandından bir görünüm

Bu kararlar, yalnızca fiziksel çevrenin düzenlenmesini değil, aynı zamanda kentsel yaşam kalitesinin artırılmasını, doğa ile uyumlu mekânlar yaratılmasını ve toplumsal etkileşimin güçlendirilmesini amaçlamaktadır. Proje; estetik, ekolojik ve sosyal açılardan sürdürülebilir bir kıyı dönüşümünü hedeflemektedir.

Bu kapsamda çalışma alanında tasarlanması düşünülen kullanımlar proje ve üç boyutlu görseller şeklinde sunulmuştur (Şekil 5-15).



Şekil 6. Çalışma alanı çeşitli fonksiyonel kullanımları içeren bir görünüm



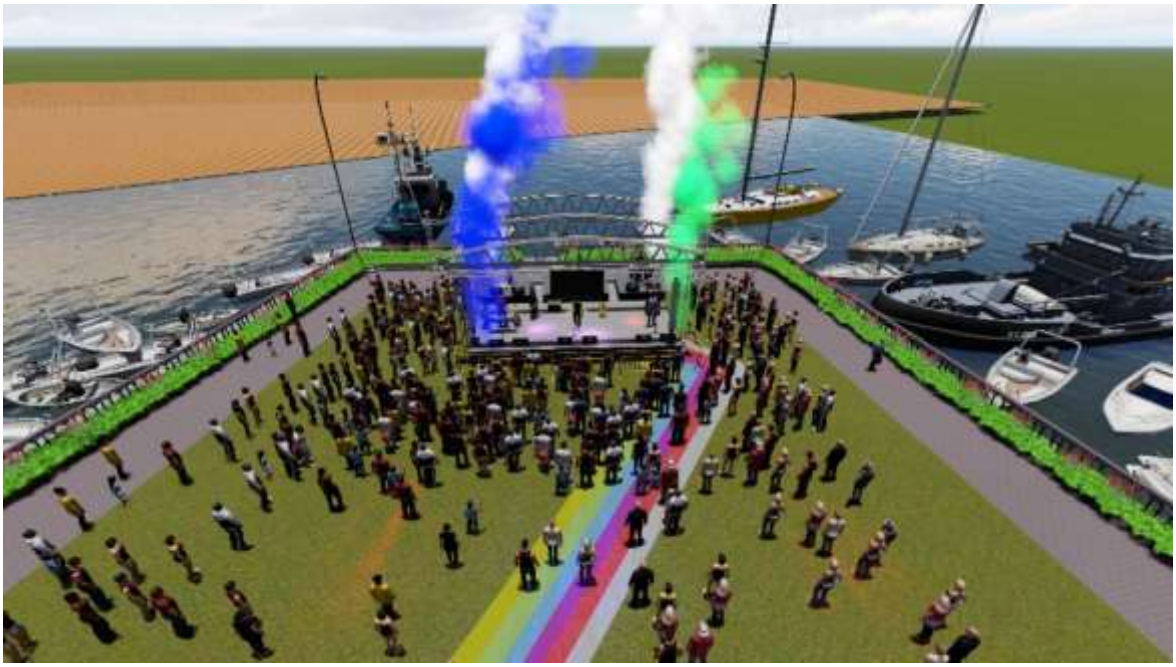
Şekil 7. Çalışma alanı deniz tarafından bir görünüm



Şekil 8. Çalışma alanı gece peyzajından bir görünüm



Şekil 9. Çalışma alanı giriş kısmından bir görünüm



Şekil 10. Çalışma alanı konser alanından bir görünüm



Şekil 11. Çalışma alanı oturma birimlerinden bir görünüm



Şekil 12. Çalışma alanı çocuk oyun alanından bir görünüm



Şekil 13. Çalışma alanı marina fonksiyonundan bir görünüm



Şekil 14. Çalışma alanı kafeterya kısmından bir görünüm



Şekil 15. Çalışma alanı kıyı bandından bir görünü

Sonuç

Bu çalışmada, İstanbul İli Küçükçekmece İlçesi Fatih Mahallesi'nde yer alan ve mevcut durumda âtıl kalan Balıkçı Adası parkı için kapsamlı bir peyzaj tasarım proje önerisi sunulmuştur. Kentsel açık yeşil alanların günümüzde artan önemi göz önüne alındığında, bu tür kıyı alanlarının rekreasyonel ve sosyal işlevlerle zenginleştirilmesi kentlerimiz için önemli bir

ihtiyaçtır. Proje ile mevcut durumda marina işleviyle sınırlı kullanımı olan alanın, çok işlevli ve estetik bir kamusal mekâna dönüşebileceği görülmüştür.

Proje kapsamında, alanın doğal potansiyelini koruyarak, farklı yaş ve kullanıcı gruplarına hitap eden çocuk oyun alanı, mesire alanı, konser alanı, dinlenme alanı ve kafeterya alanı gibi çeşitli fonksiyonel kullanımlar oluşturulmuştur. Gökkuşağı teması ile alanda çeşitlilik ve görsel zenginlik artırılmış, alanın estetik değeri yükseltilmiştir. Yaya ve bisiklet yolları, seyir noktaları, yeşil koridorlar ve bitkisel tasarım ögeleri ile kullanıcıların doğayla etkileşimi artırılmıştır.

Tasarım sürecinde AutoCAD, SketchUp, Photoshop ve Lumion gibi yazılımların kullanılması, projede görsel ve kullanım bütünlüğünün sağlanmasına, aynı zamanda projenin uygulanabilirliğinin desteklenmesine imkân sunmuştur. Önerilen peyzaj tasarımı sadece fiziksel çevrenin iyileştirilmesiyle kalmayıp, yerel halkın sosyal yaşamına katkıda bulunacak içerikler sunmaktadır. Sürdürülebilir kıyı kullanımının teşvik edilmesiyle kentsel yaşam kalitesi artırılmış olacaktır.

Sonuç olarak, bu proje önerisiyle Balıkçı Adası parkının yalnızca fiziksel olarak iyileştirilmesi değil, aynı zamanda bölge halkının sosyal etkileşimini güçlendiren, kıyı ekosistemine duyarlı ve sürdürülebilir bir kamusal alan oluşumu sağlanmıştır. Bu çalışma, benzer nitelikteki âtıl kıyı alanlarının kent yaşamına kazandırılması ve sürdürülebilir peyzaj tasarımı ilkeleriyle dönüştürülmesi adına örnek teşkil edecek bir model sunmaktadır.

Teşekkür

Çalışmada desteğini gördüğümüz Erkan Başak'a teşekkür ederiz.

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EFFECT OF DIFFERENT SALT USAGE ON BIOACTIVE AND SENSORY PROPERTIES OF TABLE OLIVES

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ABSTRACT

In this study, differences in the bioactive and sensory properties of table olives prepared using three different salts (Himalayan salt, rock salt, sodium-reduced salt) were determined. The highest pH was determined in sodium-reduced salt with 4.58. The titratable acidity of the brine was observed between 0.20% (sodium-reduced salt brine) and 0.27% (rock salt brine). The highest total phenolic content (215.93 mg/100 g) was determined in olives using rock salt. Antioxidant activities were recorded as 0.56 mmol/100 g in all samples. The highest total flavonoid content with 2567.14 mg/100 g was observed in olives using Himalayan salt, followed by rock salt with 1520.48 mg/100 g. The amounts of hydroxytyrosol (28.43 mg/100 g), verbascoside (19.06 mg/100 g) and oleuropein (17.74 mg/100 g) in olives prepared with rock salt were found to be the highest when compared to olives prepared with other salts. The tyrosol concentration of Himalayan salted olives was determined to be at the maximum level with the value of 10.71 mg/100 g. Luteolin and caffeic acid contents of table olives were not significantly affected by the use of different salts, and the lowest values were found to be 9.17 mg/100 g (rock salt) and 3.45 mg/100 g (sodium-reduced salt), respectively. According to results of sensory properties, the table olive with the highest score in all parameters was prepared using rock salt, followed by himalayan salt.

Keywords: Table olive, antioxidant activity, salt, bioactive properties, oleuropein

Introduction

Table olives are products obtained by removing the bitterness of cultivated olive tree fruits in accordance with the technique, subjecting them to lactic acid fermentation or not, and adding lactic acid and/or other additives when necessary, and subjecting them to pasteurization or sterilization processes or not (TS-774, 1993). The main phenolic compounds of olives are; phenolic glycosides such as oleuropein, verbascoside, ligsitroside, flavonoids, flavonol glycosides, anthocyanins and their glycosides, phenolic acids (Ryan & Robards, 1998; Keçeli & Gordon, 2001; Savaş & Uylaşer, 2013). Phenolic compounds found in olive fruits are responsible for the bitter taste in olives (Cemeroğlu et al., 2001). In table olive production, different methods such as alkali treatment, directly soaking in water or brine, and salt treatment are used, but the common goal is to sweeten and preserve the olive (Arroyo-López et al., 2015). In order to sweeten the olive, the oleuropein substance, which is the source of the bitter taste, must be removed from the fruit, and in order to preserve the olive, the beneficial microorganisms in the olive microflora must consume the carbohydrates in the fruit and prevent the development of pathogenic microorganisms by producing lactic acid. For this purpose, leaving the olives to ferment in brine is a widely used method in the production of many table olive varieties (Aktan & Kalkan, 2000; Panagou & Katsaboxakis, 2006). Preservation and fermentation in salt water is a traditional food preservation method used due to its low energy consumption and cost. In this preservation method, salt reduces water activity, inhibits the growth of undesirable microorganisms and helps improve taste (Ross et al., 2002). All preparation processes of fermented table olives include a immersion step in a salt solution where fermentation takes place. The final product will be consumed by consumers without any pretreatment, since table olives are referred to as "ready-to-eat food". Any changes during processing may lead to the risk of spoilage or safety issues. Salt (NaCl) plays an important role in fermented foods because it increases the speed of the fermentation process by increasing the diffusion of different compounds out of the cells, inhibits the growth of undesirable bacteria and fungi present in fresh food, and supports the growth of fermentative microorganisms. A large diversity of LAB and/or yeast species is usually observed at the beginning of fermentations. As the processes progress, some species disappear and others develop, and each phase is associated with different species (Alves et al., 2012; Bleve et al., 2014, Hurtado et al., 2008, Nisiotou et al., 2010; Pereira et al., 2008). In this study, the effect of different salts (Himalayan salt, rock salt and sodium-reduced salt) on the bioactive and sensory properties of table olives was investigated.

Materials and Methods

Materials

Ayvalık variety olives were provided in November. The water of the olives was changed in the morning and evening and the bitterness process was applied for 7 days and at the end of the 7 days, the olives were prepared using 10% brine with three different salt types (rock salt, Himalayan salt, 50% sodium reduced salt). They were left to ferment for 2 months before the analyses were carried out.

Methods

pH determination

According to Cemeroğlu (1992), pH measurement in the brine was carried out using a pH-meter.

Titration acidity determination

The titration acidity of the brine was determined by titration with 0.1 N NaOH together with phenolphthalein indicator and given as a percentage (Uylaşer & Başoğlu, 2011).

Extraction of phenolic compounds from olive fruit

The olive pulp (1.5 g) separated from the pits and crushed was weighed and 20 ml of methanol/water (80:20, v/v) was added. After mixing for 3 min using vortex, the extract was filtered through Whatman filter paper number 40. The hexane (20 ml) was added to the filtrate and mixed, and the remaining phase was used for analysis by passing through 0.45 µm syringe filters (Vinha et al., 2005; Yorulmaz et al., 2013).

Total phenolic content

The total phenolic content of olive extracts was determined using Folin Ciocalteu (FC) reagent (Yoo et al., 2004). The extract (0.5 ml) was mixed with 2.5 ml of FC reagent and 1.5 ml of sodium carbonate solution. The absorbance values of the samples kept at room temperature and in the dark for 2 hours were measured at 725 nm.

Total flavonoid content

Total flavonoid content was determined according to Dewanto et al. (2002). The extracts were diluted with distilled water. After adding 5% NaNO2 solution to each test tube, 10% AlCl3 solution was added 5 minutes later and 1.0 M NaOH solution was added 6 minutes later. The total volume was filled with water until it became 5 ml and the test tubes were mixed well. The absorbance was measured at 510 nm.

Antioxidant activity

The antioxidant activity of olive extracts was determined using 2,2-diphenyl-1-picrazyl (DPPH) according to Lee et al. (1998). The extract (0.1 ml) was mixed with 2 ml of DPPH solution and the absorbance values of the samples kept at room temperature and in the dark for 30 min were measured at 517 nm.

Determination of phenolic components

The phenolic component profile of olive extracts was performed using high-performance liquid chromatography (HPLC) at 280 nm.

Working conditions;

Instrument :Shimadzu LC 10A vp, Kyoto, Japan

Software :PC running Class VP chromatography manager software (Shimadzu, Japan)

Injection volume :40 µl

Column :Inertsil ODS3 analytical column (GL Sciences, Japan), (5 µm, 25 cm x 4.6 mm i.d.)

Mobile phase :A (2% formic acid aqueous solution), B (methanol)

Flow rate :0.85 ml/min

Detector :Shimadzu SPD-M20 A Diode Array Detector

Temperature :40 °C

Sensory Analysis

Sensory properties of table olives were determined by applying scoring test. This test was performed by 10 trained panelists to determine the characteristics of olives. Panelists evaluated the samples in terms of taste, odor, color, texture and bitterness. Each panelist evaluated the sensory characteristics of the olives with the following scores: 1 = very bad, 2 = bad, 3 = average, 4 = good, 5 = very good (Pagliarini & Rastelli, 1994).

Findings and Discussion

The moisture, pH and titratable acidity results of the samples are given in Table 1. According to the results of moisture content, the highest moisture content with 61.85% was determined in olives cured with Himalayan salt; while no significant change was observed in the moisture contents of olives cured with rock salt (59.21%) and reduced sodium salt (58.85%). The highest pH was determined in sodium-reduced salt with 4.58. According to the study conducted by Cabral et al. (2018) with Cobrançosa variety olives, the pH value of the samples cured with 8% NaCl was reported as 4.46, and the pH value of the samples cured with 4% NaCl + 4% KCl concentration was reported as 4.52. The titratable acidity of the brine was observed between 0.20% (sodium-reduced salt) and 0.27% (rock salt brine). In the study conducted to determine the total acidity of olive samples taken from different regions of Bursa province, the total acidity of the olive samples was found to be 0.56-0.71 g/100 g for pickled black olives; 0.31-0.45 g/100 g for pickled green olives; and 0.71 g/100 g for pickled olives (Atlı, 2020).

Table 1. Physicochemical properties of olive samples

Olive samples	Moisture content (%)	pH	Titratable acidity (%)
Rock salt	59.21 ± 0.79	4.51 ± 0.00	0.27 ± 0.01
Himalaya salt	61.85 ± 0.43	4.48 ± 0.02	0.22 ± 0.03
Sodium reduced salt	58.85 ± 0.22	4.58 ± 0.01	0.20 ± 0.01

The bioactive properties of the pickled olive samples are shown in Table 2. When the total phenolic content was evaluated, the highest concentration (215.93 mg/100 g) was obtained in olives cured with rock salt, while the total phenolic contents were determined as 141.30 mg/100 g using Himalayan salt and 166.67 mg/100 g with sodium reduced salt. In a study, the total phenolic content was determined as 155 mg/100 g in olives fermented in 8% brine and 168

mg/100 g in samples cured with 4% NaCl + 4% KCl concentration, and similar results were found in the present study (Cabral et al., 2018). In a different study, the change in the total phenolic content of different olive varieties depending on the harvest time was examined. According to this study, it was reported that the total phenolic content of Ayvalık variety olives varied between 102.30 mg/100 g in the 1st month (August) and 287.29 mg/100 g in the 5th month (December) (Fındık, 2017). In another study, Uslu olive (fresh) had the highest value with 421.0 mg CAE/100 g total phenolic substance, followed by Gemlik, Ayvalık, Memecik and Domat olives with 274.9, 250.8, 208.2 and 189.8 mg CAE/100 g, respectively. In processed olive varieties, the highest phenolic content was determined in Uslu variety with a decrease from 421.0 mg CAE/100g to 394.9 mg CAE/100g, while the lowest value was determined in Ayvalık olive with a decrease from 250.8 mg CAE/100g to 133.2 mg CAE/100g (Irmak et al., 2010).

Antioxidant activity was found to be the same in all pickled olives with a value of 0.56 mmol/100 g. According to the study of Fındık (2017), the antioxidant activity of Ayvalık variety olives varied between 83.685% in the 1st month (August) and 76.190% in the 5th month (December). In a study on the effect of processing methods on the antioxidant capacity of table olives, the antioxidant capacity was determined as 348.8-456.7 µmol trolox/100g according to the DPPH method in 10 different samples, and the highest value was reported to be determined in pickled black olives and the lowest value in pickled green olive samples (Atlı, 2020).

The highest total flavonoid content with a value of 2567.14 mg/100 g was determined in olives prepared with Himalayan salt, followed by rock salt with 1520.48 mg/100 g. The lowest value with 1124.29 mg/100 g was obtained in olive sample using sodium reduced salt. In a study, when the flavonoid content of Gemlik olives was examined according to their ripening periods on the tree (green, variegated, rabbit heart, black), the lowest flavonoid content was recorded in green olives. The flavonoid amounts of olives harvested in the 3rd stage of ripening were higher than those in other ripening stages. The flavonoid amounts of Gemlik type olives increased until the 3rd ripening stage, and decreased in the 4th ripening period with the full ripening of the olives. It was reported that total flavonoid contents were recorded as 136.88 mg/100 g, 275.55 mg/100 g, 397.03 mg/100 g, 313.44 mg/100 g, respectively, according to the ripening level (Kose et al., 2018).

Table 2. Bioactive properties of olive samples

Olive samples	Total phenolic content (mg/100 g)	Antioksidan activity (mmol/100 g)	Total flavonoid content (mg/100g)
Rock salt	215.93 ± 11.18	0.56 ± 0.00	1520.48 ± 33.11
Himalayan salt	141.30 ± 7.78	0.56 ± 0.00	2567.14 ± 19.79
Sodium reduced salt	166.67 ± 4.84	0.56 ± 0.00	1124.29 ± 7.56

Table 3 shows the phenolic compounds of pickled olives. When the changes in phenolic compounds according to the salt type were examined, the highest values were recorded in the amounts of hydroxytyrosol (28.43 mg/100 g), verbascoside (19.06 mg/100 g) and oleuropein (17.74 mg/100 g) in olives cured with rock salt. The tyrosol concentration of the Himalayan salt sample was found to be higher than the other samples with a value of 10.71 mg/100 g. Although no significant change was observed in the amount of luteolin, the lowest content was seen in the olives cured with rock salt as 9.17 mg/100 g. Similarly, there was no significant change in the amount of caffeic acid, but the lowest value of 3.45 mg/100 g was detected in the olives cured with 50% reduced sodium salt.

Table 3. Phenolic compounds of olive samples

Phenolic compounds (mg/100 g)	Rock salt	Himalaya salt	Sodium reduced salt
Hydroxytyrosol	28.43 ± 7.63	12.80 ± 0.78	11.46 ± 0.51
Tyrosol	10.71 ± 0.93	13.82 ± 0.84	10.29 ± 0.39
Caffeic acid	4.13 ± 0.56	4.12 ± 0.36	3.45 ± 0.31
Verbascoside	19.06 ± 3.65	15.56 ± 1.13	14.50 ± 0.94
Oleuropein	17.74 ± 1.76	14.19 ± 0.22	13.41 ± 0.58
Luteolin	9.17 ± 0.02	9.25 ± 0.09	9.26 ± 0.02

In a study, it was determined that verbascoside was less than 0.02% in olive varieties grown in Portugal. It was also determined that verbascoside was low in varieties with the highest amount of oleuropein (Vinha et al., 2005). In a study investigating the effects of location and olive processing methods on phenolic compounds in Gemlik variety olives, it was reported that hydroxytyrosol and tyrosol contents in olive samples varied between 4.58-195.70 mg/kg and 0.57-47.24 mg/kg, respectively. In the same study, luteolin values in Gemlik variety olive samples varied between 0.17 mg/kg and 53.56 mg/kg, while oleuropein values were reported between 0.16 mg/kg and 58.94 mg/kg (Demir, 2024). In a different study, the amount of hydroxytyrosol in Gemlik variety olives was reported as 368 mg/kg (Ghrobel et al., 2018). In another study, it was reported that the amount of hydroxytyrosol in fresh olive samples of Sarıulak olive variety obtained from different regions varied between 38.7 mg/kg and 675.3 mg/kg (Arslan & Özcan, 2011). In the study conducted by Othman et al. (2009), the amount of hydroxytyrosol in fresh olives of Meski variety was found to be between 2198-2832 mg/kg. In another study, the amount of luteolin in fresh olive samples was determined as 248.72 mg/kg (Yorulmaz et al., 2012). The lowest amount of tyrosol in olives obtained from Gemlik variety and Mudanya region was reported as 19.08 mg/kg (Uylaser, 2015). According to the present study, it is thought that the differences observed in phenolic compound contents are due to location, olive variety and process parameters.

The sensory properties of table olives are presented in Table 4. When the sensory analysis results were evaluated, the sample with the highest score in all parameters was rock salt, followed by himalayan salt. The lowest scores were recorded for sodium reduced salt compared to the other two samples. In the study conducted by Ratogi et al. (2007) investigating the effect of replacing NaCl with CaCl2 and/or KCl on the sensory properties of Maçanilha Algarvia table olives, it was reported that olives fermented with 8% NaCl and 4% NaCl + 4% KCl brine obtained the highest scores for flavor and general properties, while samples processed with other brine combinations (4% NaCl + 4% CaCl2 −4% KCl + 4% CaCl2 and 2.7% NaCl + 2.7% KCl + 2.7% CaCl2) were unacceptable.

Table 4. Sensory properties of olive samples

Olive samples	Taste	Smell	Colour	Texture	General appearance
Rock salt	4.80 ± 0.45	5.00 ± 0.00	4.60 ± 0.55	4.80 ± 0.45	4.80 ± 0.45
Himalaya salt	4.80 ± 0.45	4.80 ± 0.45	4.40 ± 0.55	4.60 ± 0.55	4.60 ± 0.55
Sodium reduced salt	3.60 ± 0.89	4.20 ± 0.84	4.20 ± 0.84	4.40 ± 0.55	4.40 ± 0.55

Conclusion and Recommendations

The effect of salt on biyoactive properties and sensory attributes of table olives was investigated. The highest total phenolic content, hydroxytyrosol, verbascoside and oleuropein were

recorded in the olives prepared with rock salt, while the table olives prepared with himalayan salt contained higher amounts of total flavonoid and tyrosol. Similarly, when all values were considered, the lowest values except for total phenolic content were determined in samples prepared with 50% reduced sodium salt.

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EFFECTS OF DIFFERENT NITROGEN FERTILIZATION ON SILAGE QUALITY OF SOME SWEET SORGHUM CULTIVARS GROWN UNDER SECOND CROP CONDITIONS

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ABSTRACT

This study was conducted at B.U.U. Faculty of Agriculture TUAM experimental areas in 2022 and 2023 to determine the effects of different nitrogen doses (0, 8, 16 and 24 kg/da) on the silage quality of some sweet sorghum varieties (Gülşeker, Erdurmuş and Uzun) grown as second crop under the ecological conditions of Bursa.Harvesting of plants for silage was carried out at the milk-dough stage of the plants. Harvested plant samples were shredded into 1.5-2 cm pieces, then filled into 1 litre anaerobic jars and left to fermentation for 60 days under laboratory conditions. The jars were opened after 60 days and the dry matter rate, pH, crude protein, ADF and NDF rates were analysed. According to the two-year average results obtained from the study, significant differences were found among the varieties in terms of the analysed parameters. The highest crude protein rate was found in Uzun variety, the lowest ADF and NDF rates were found in Erdurmuş variety. Increasing nitrogen doses significantly affected the other parameters of the silages except dry matter and ADF rates. In terms of nitrogen doses, the highest crude protein rate was obtained from 24 kg/da nitrogen dose, the lowest pH value were obtained from 0 and 16 kg/da nitrogen doses and the lowest NDF rate was obtained from 0 and 8 kg/da nitrogen doses. In conclusion, it can be recommended to prefer Erdurmuş variety and to use 16 kg/da nitrogen dose for a well-balanced silage in terms of fermentation quality, nutrient content and digestibility of silages in cultivation in similar ecological regions.

Keywords: Nitrogen, second crop, silage quality, sweet sorghum

İKİNCİ ÜRÜN KOŞULLARINDA YETİŞTİRİLEN BAZI ŞEKER SORGUM ÇEŞİTLERİNDE FARKLI AZOT DOZLARININ OTUN SİLAJ KALİTESİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışma, Bursa ekolojik koşullarında ikinci ürün olarak yetiştirilen bazı şeker sorgum çeşitlerinde (Gülşeker, Erdurmuş ve Uzun) değişik azot dozlarının (0, 8, 16 ve 24 kg/da) otun silaj kalitesi üzerindeki etkilerini belirlemek amacıyla B.U.Ü. Ziraat Fakültesi TUAM deneme alanlarında 2022 ve 2023 yıllarında yürütülmüştür. Silaj amacıyla bitki hasadı, tanelerin süt-hamur olum döneminde yapılmıştır. Hasat edilen bitki örnekleri 1.5-2 cm boyutlarında parçalanmış, ardından 1 litrelik anaerobik kavanozlara sıkıştırılarak doldurulmuş ve laboratuvar koşullarında 60 gün süreyle fermantasyona bırakılmıştır. Hazırlanan kavanozlar 60 gün sonra açılmış ve silajlarda kuru madde oranı, pH değeri, ham protein, ADF ve NDF oranları gibi özellikler incelenmiştir. Araştırmadan elde edilen iki yıllık ortalama sonuçlara göre; çeşitler arasında incelenen özellikler açısından önemli farklılıklar ortaya çıkmıştır. Araştırmada, en yüksek ham protein oranı Uzun çeşidinde, en düşük ADF ve NDF oranları ise Erdurmuş çeşidinde tespit edilmiştir. Artan azot dozları silajların kuru madde ve ADF oranı hariç incelenen diğer özellikleri önemli ölçüde etkilemiştir. Azot dozları bakumından en yüksek ham protein oranı 24 kg/da azot dozundan, en düşük pH değeri 0 ve 16 kg/da azot dozlarından, en düşük NDF oranı ise 0 ve 8 kg/da azot dozlarından elde edilmiştir. Sonuç olarak; benzer ekolojik bölgelerde yapılacak yetiştiricilikte silajların fermantasyon kalitesi, besin içeriği ve sindirilebilirliği açısından dengeli bir ot silaj için Erdurmuş çeşidinin tercih edilmesi ve 16 kg/da azot dozunun kullanılması önerilebilir.

Anahtar kelimeler: Azot, ikinci ürün, silaj kalitesi, şeker sorgum

Giriş

Ülkemizde çayır ve mera alanları ile tarla tarımında yetiştirilen yem bitkileri, kaba yem ihtiyacını karşılayan en önemli iki kaynaktır. Hayvan beslenmesi ve kaba yem temininde çayır ve meraların rolü oldukça büyüktür (Okçu, 2020). Ancak, çayır ve mera alanlarının amaç dışı kullanımı ile erken ve aşırı otlatma gibi sorunlar, bu alanların önemli bir kısmının bitki örtüsünden yoksun kalmasına ve verimlerinin düşmesine yol açmaktadır. Bu nedenle, ülkemizdeki kaba yem açığının kısa sürede kapatılmasında tarla tarımında yetiştirilen yem bitkileri önemli bir rol üstlenecektir. Bitkisel üretim destekleri kapsamında geliştirilen ekim modeli sayesinde yem bitkileri ekim alanlarında %10'luk bir artış sağlanmıştır. Bu teşvik edilen yem bitkileri arasında sorgum (*Sorghum bicolor*) da bulunmaktadır (Yücel ve ark., 2018). Sorgum, tarih boyunca "Verimli Hilal" olarak bilinen Mezopotamya'da kültüre alınmıştır. Kültüre alındığı günden bu yana Anadolu'da da yetiştirilen sorgum; darı, koca darı, boynu eğri darı ve gılgıl gibi farklı isimlerle anılmaktadır. Şemseddin Sâmi, "tarla" kelimesinin darı kökenli olduğunu ve bu terimin darı ekili alanı ifade ettiğini belirtmektedir. Ayrıca, geçici kuraklıklara karşı yüksek toleransı ve kuraklık koşulları sona erdikten sonra yeniden büyüme yeteneği sayesinde sorgum "bitkiler âleminin devesi" olarak tanımlanmaktadır (Sezgin ve Alatürk, 2023). Üretim özellikleri ve kullanım alanlarına göre sorgum, şeker sorgum, tane sorgum ve yem sorgum olarak üç gruba ayrılmaktadır (Motsi ve ark., 2022). Şeker sorgum türleri, abiyotik stres koşullarına mısıra göre daha fazla tolerans gösterir. Bu nedenle, gelecekte olumsuz çevre koşullarının ortaya çıkabileceği bölgelerde şeker sorgum, silajlık mısırın yerini alabilecek bir potansiyele sahiptir.

Son yıllarda farklı şeker sorgum genotiplerinin silaj kalitesine yönelik olarak yapılmış olan çalışmalarda genotipler arasında önemli farklılıkların olduğu (Orrico Junior ve ark., 2015; Geren ve ark., 2019; Yücel ve Erkan, 2020;) bildirilmiş olmakla birlikte silaj kalitesi açısından azot dozlarının etkinliği üzerine sınırlı sayıda araştırma (Girgin, 2012; Sadigfard, 2016) yapılmıştır. Azot, bitki gelişmesinde hayati fonksiyona sahip bir bitki besin maddesi olup bitkiler tarafından alınan azota bağlı olarak bitki bünyesinde azotlu bileşikler artmakta ve vejetatif aksam zenginleşmektedir (Sadighfard, 2016). Bu nedenle, her bir çeşit ve yetiştirme koşulu için en uygun azot miktarının belirlenmesi, sürdürülebilir tarım uygulamaları açısından gereklidir. Bu noktadan hareket edilerek bu çalışma, Bursa ekolojik koşullarında ikinci ürün olarak yetiştirilen bazı şeker sorgum çeşitlerinde artan azot dozlarının otun silaj kalitesi üzerindeki etkilerini belirlemek amacıyla yapılmıştır.

Materyal ve Yöntem

Araştırma, 2022 ve 2023 yıllarında B.U.Ü. Ziraat Fakültesi TUAM deneme alanlarında tarla denemesi olarak tesadüf bloklarında bölünmüş parseller deneme düzenine göre 3 tekrarlamalı olarak yürütülmüştür. Denemelerde ana parsellere şeker sorgum çeşitleri (Gülşeker, Erdurmuş ve Uzun), alt parsellere ise azot dozları (0, 8, 16 ve 24 kg/da) yerleştirilmiştir. Araştırmada, her bir alt parselde sıra arası 70 cm olacak şekilde 5 m boyunda sıralar açılmış ve ekim 5 Temmuz 2022 ve 6 Temmuz 2023 tarihlerinde yapılmıştır. Denemede hasat bitkilerin süt-hamur olum döneminde elle toprak seviyesinden biçilerek yapılmıştır. Hasat döneminde her parselden, parseli temsil eden beş bitki alınmış ve bitkiler tek sıralı silaj makinesinden geçirilmiştir. Parçalama işlemi 1.5-2 cm boyutlarında yapılmıştır. Parçalanan örnekler laboratuvarda bir pres yardımıyla 1 litrelik anaerobik kavanozlara sıkıştırılarak doldurulmuş ve ardından etiketlenmiştir. Hazırlanan kavanozlar 60 gün süreyle fermantasyona bırakılmıştır. Fermantasyon süreci sonunda açılan kavanozların her birinden en az 150 g örnek alınmış ve 70 °C'de 48 saat kurutularak kuru madde oranları belirlenmiştir. Ayrıca, silajların pH değerlerini

belirlemek amacıyla silajlardan 40 g örnek alınıp üzerine 360 ml saf su eklenmiş ve 3 dak. çalkalanmıştır. Çalkalama işlemi tamamlandıktan sonra örnekler süzülmüş ve bu süzüklerde pH değeri ölçülmüştür (Budaklı Çarpıcı, 2009). Kuru madde oranını belirlemek amacıyla kullanılan örnekler öğütülmüş ve bu örneklerde ham protein oranı, ADF oranı ve NDF oranını belirlemek amacıyla analizler yapılmıştır (AOAC, 1990;Van Soest ve ark.,1991).

İki süreyle yürütülen tarla denemesinden elde edilen materyaller kullanılarak yapılan silajlardan elde edilen veriler, yıllar üzerinden birleştirilmiş ve "Tesadüf Bloklarında Bölünmüş Parseller Deneme Düzeni'ne uygun olarak varyans analizine tabi tutulmuşlardır (Turan, 1995). Hesaplamalarda JMP Pro 13 paket programını kullanılmıştır. Önemlilik testlerinde %1 ve %5, farklı grupların belirlenmesinde ise %5 olasılık düzeyi dikkate alınmıştır. Araştırmada, farklı grupların belirlenmesi amacıyla AÖF testi kullanılmıştır.

Bulgular ve Tartışma

Araştırmada iki yılın birleştirilmiş verileri üzerinden varyans analizleri yapılmıştır. Varyans analizi sonuçlarına göre; çeşitlerin silaj kuru madde oranı, pH değeri, ADF ve NDF oranları üzerine etkileri %1, ham protein oranı üzerine etkisi ise %5 olasılık düzeyinde önemli bulunmuştur. Azot dozlarının silajın pH değeri ve ham protein oranı üzerine etkisi %1 olasılık düzeyinde önemlidir. Ayrıca, çeşit x azot dozu interaksiyonunun ham protein oranı ve NDF oranı üzerine etkisi %5 olasılık düzeyinde önemli bulunmuştur (Çizelge 1).

Çizelge 1. İkinci ürün koşullarında yetiştirilen şeker sorgum çeşitlerinde farklı azot dozlarının silaj kalite özelliklerine ilişkin varyans analizi sonuçları (KO)

Varyasyon Kaynağı	SD	KM	pH	HP	ADF	NDF
Yıl (Y)	1	*	**	**	öd	öd
Çeşit	2	**	**	*	**	**
Ç X Y	2	**	*	*	**	**
Azot Dozu	3	öd	**	**	öd	öd
Y X AD	3	*	**	öd	öd	öd
Ç X AD	6	öd	öd	*	öd	*
Y X Ç X AD	6	öd	öd	*	öd	öd

Y: Yıl, Ç:çeşit, AD: azot dozu, SD: Serbestlik derecesi, öd: önemli değil

KM: Kuru madde, HP: Ham protein, ADF: Asit deterjanda çözünmeyen lif, NDF: Nötr deterjanda çözünmeyen lif,

** ,*; Sırasıyla % 1 ve % 5 düzeyinde önemlidir.

Çeşitlere ait silajların kuru madde oranları Çizelge 2'de verilmiş olup, en yüksek kuru madde oranı %31.69 ile Uzun çeşidinden elde edilmiştir. Farklı şeker sorgum çeşitleri ile yapılan silajlarda kuru madde oranları büyük farklılık göstermiştir. Örneğin; Durul (2016) Bornova/İzmir koşullarında Rio çeşidinde %25.20; Güre (2016) İzmir koşullarında Keller çeşidinde %24.70; Ertekin (2021) Hatay koşullarında Erdurmuş çeşidinde %26.56 olduğu belirtilmiştir. İki yıl süreyle yürütülen çalışmamızda en düşük pH değerinin aralarındaki sayısal farklılıklar istatistiki açıdan önemsiz olan Erdurmuş (3.86) ve Gülşeker (3.87) çeşitlerinden elde

edildiği saptanmıştır (Çizelge 2). Çalışmamızda silaj pH'sı bakımından çeşitler arasında farklılıklar tespit edilmiştir. Elde ettiğimiz bu sonuçlar bazı araştırıcılar tarafından bildirilen sonuçlarla uyum içerisindedir (Geren ve ark., 2019; Yücel ve Erkan, 2020). En yüksek ham protein oranı %8.39 ile Uzun çeşidinden, en düşük ham protein oranı ise %6.57 ile Gülşeker çeşidinden elde edildiği belirlenmiştir (Çizelge 2). Çeşitler arasında silajın ham protein oranını Orrico Junior ve ark. (2015) Brezilya koşullarında %4.10-4.98; Geren ve ark. (2019) Bornova/İzmir koşullarında %8.10-8.60; Yücel (2020) Adana koşullarında %3.36-5.01; Yücel ve Erkan (2020) Çukurova koşullarında %4.08-4.79 arasında değişim gösterdiğini bildirmişlerdir. Çeşitler bakımından en düşük ADF ve NDF oranları (sırasıyla %31.17 ve %49.69) Erdurmuş çeşidinden elde edilmiştir. Çeşitlere bağlı olarak silajının NDF oranının Orrico Junior ve ark. (2015) Brezilya koşullarında %43.63-48.32; Geren ve ark. (2019) Bornova koşullarında %45.0-46.7; Yücel (2020) Adana koşullarında %42.58-46.89 değerleri arasında değişim gösterdiğini rapor etmişlerdir. ADF ve NDF Değerleri Arasındaki Farklılıkların Büyük Ölçüde Çeşit Farklılığından Ve Ekolojik Koşullardan Kaynaklandığı Düşünülmektedir.

Çizelge 2. İkinci ürün koşullarında yetiştirilen şeker sorgum çeşitlerinde farklı azot dozlarının silajın bazı kalite özellikleri üzerine etkisi (iki yıllık ortalama veriler)

Çeşit	Azot Dozları (kg/da)				Ortalama
	0	8	16	24	
Kuru madde oranı (%)					
Gülşeker	27.54	27.63	26.17	27.42	**27.19 C**
Erdurmuş	29.24	29.65	29.35	30.21	**29.62 B**
Uzun	31.23	31.74	31.35	32.44	**31.69 A**
Ortalama	**29.34**	**29.67**	**28.96**	**30.02**	
pH					
Gülşeker	3.84	3.91	3.87	3.87	**3.87 B**
Erdurmuş	3.90	3.88	3.80	3.94	**3.86 B**
Uzun	3.95	3.97	3.92	9.99	**3.95 A**
Ortalama	**3.86 B**	**3.92 A**	**3.87 B**	**3.93 A**	
Ham protein oranı (%)					
Gülşeker	5.60 ef	5.23 f	7.26 bc	7.54 ab	**6.41 C**
Erdurmuş	6.13 de	6.64 cd	7.26 bc	7.84 ab	**6.97 B**
Uzun	7.45 ab	7.47 ab	7.90 ab	8.19 a	**7.75 A**
Ortalama	**6.39 B**	**6.45 B**	**7.47 A**	**7.86 A**	
ADF (%)					
Gülşeker	36.94	36.70	35.84	34.73	**36.05 A**
Erdurmuş	29.73	30.85	31.67	32.44	**31.17 C**
Uzun	33.87	33.63	31.93	32.16	**32.90 B**
Ortalama	**33.51**	**33.73**	**33.15**	**33.11**	
NDF (%)					
Gülşeker	57.01 a	57.00 a	54.76 ab	55.65 ab	**56.09 A**
Erdurmuş	48.53 d	47.83 d	49.56 cd	52.83 bc	**49.69 B**
Uzun	56.54 a	56.94 a	53.40 ab	53.76 ab	**55.16 A**
Ortalama	**54.02**	**53.92**	**53.56**	**54.08**	

Yıl. çeşit, azot dozu ve çeşit x azot dozu interaksiyonuna ait önemli çıkan ortalamalarda aynı harfi taşıyan değerler arasında 0.05 olasılık düzeyinde fark yoktur.

Azot dozlarının etkisi incelendiğinde; kuru madde oranı artan azot dozlarından etkilenmemiş ve kuru madde oranları %28.96-30.02 aralığında değişim göstermiştir. En düşük pH değeri 3.86 ile azot uygulanmayan parsellerden elde edilmiş, bunu aynı istatistiki grupta yer alan 16 kg/da azot dozu (3.87) takip etmiştir (Çizelge 2). Girgin (2012) Bornova koşullarında yürüttüğü bir çalışmada şeker sorgum bitkisine uygulanan azot dozlarının silajın kuru madde oranı ve pH üzerine etkisinin önemli olduğunu bildirmiştir. Araştırıcı, azot dozlarına bağlı olarak kuru madde oranlarının %27.93-33.57 ve pH değerlerinin 3.70-3.86 arasında değiştiğini belirlemiştir. Artan azot dozu azotsuz koşullara göre silajın ham protein oranı artırmış ve en yüksek ham protein oranı 16 kg N/da ve 24 kg N/da uygulamalarından elde edilmiştir (Çizelge

2). Sadigfard (2016) şeker sorgum silajının ham protein oranı bakımından azot dozları arasında istatistiki olarak önemli farkların olduğunu belirlemiş ve ham protein oranlarının ilk yıl %4.9-7.4, ikinci yıl ise %4.6-6.4 değerleri arasında değiştiğini bildirmiştir. Artan azot dozu uygulamaları ADF ve NDF oranlarını etkilememiş ve ADF oranı %33.11-33.73, NDF oranı ise %54.02-53.92 arasında değişim göstermiştir (Çizelge 2).

Çeşitlerin artan azot dozlarına verdikleri tepkiler farklılık göstermiş ve bu durum da çeşit x azot dozu interaksiyonunun önemli çıkmasına neden olmuştur. İnteraksiyon incelendiğinde; silajda en yüksek ham protein oranı Uzun çeşidinin 24 kg/da azot dozu uygulamasından, en düşük NDF oranı ise Erdurmuş çeşidinin 0 kg/da ve 8 kg/da azot dozu uygulamalarından elde edilmiştir (Çizelge 2).

Sonuç ve Öneriler

İkinci ürün koşullarında elde edilen araştırma sonuçlarına göre; en yüksek ham protein oranı Uzun çeşidinde, en düşük ADF ve NDF oranları ise Erdurmuş çeşidinde tespit edilmiştir. Artan azot dozlarının kuru madde ve ADF oranları üzerine önemli bir etkisi gözlenmemiştir. En yüksek ham protein oranı 24 kg/da azot dozundan, en düşük pH değeri ise 0 kg/da ile 16 kg/da azot dozlarından elde edilmiştir. Silajda en düşük NDF oranı ise Uzun çeşidinin 0 kg/da ve 8 kg/da azot dozu uygulamalarının yetiştiği parsellerde belirlenmiştir. Erdurmuş çeşidi, çalışmada en düşük ADF ve NDF oranlarına sahip olmasıyla öne çıkmıştır. Düşük ADF oranı, yem sindirilebilirliğini artırarak hayvanların enerji alımını desteklerken, düşük NDF oranı ise yem tüketilebilirliğini yükselterek hayvan performansını iyileştirmektedir. Artan azot dozları silajların kuru madde ve ADF oranı hariç incelenen diğer özellikleri önemli ölçüde etkilemiştir. Azot dozu açısından, 0 kg/da azot uygulaması ile Erdurmuş çeşidinde en düşük NDF oranı elde edilmiş, bu da lif içeriği daha düşük ve hayvanlar tarafından daha kolay sindirilebilen bir yem elde edilmesini sağlamıştır. Ancak azotsuz uygulama ot verimi ve protein oranını düşürebileceğinden, düşük lif ve yeterli verimi korumak için 8 kg/da ile 16 kg/da azot dozları da uygulanabilir. Sonuç olarak; benzer ekolojik bölgelerde yapılacak yetiştiricilikte silajların fermantasyon kalitesi, besin içeriği ve sindirilebilirliği açısından dengeli bir silaj için Erdurmuş çeşidinin tercih edilmesi ve 16 kg/da azot dozunun kullanılması önerilebilir.

Teşekkür ve Bilgi Notu

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THE EFFECTS OF INCREASING NITROGEN DOSES ON THE SILAGE QUALITY OF BAGASSE IN SOME SWEET SORGHUM CULTIVARS GROWN UNDER SECOND CROP CONDITIONS

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ABSTRACT

This study was conducted B.U.U. Faculty of Agriculture TUAM experimental areas in 2022 and 2023 to determine the effects of increasing nitrogen doses (0, 8, 16 and 24 kg/da) on the silage quality of bagasse in some sweet sorghum varieties (Gülşeker, Erdurmuş and Uzun) grown as second crop under Bursa ecological conditions. Harvesting of plants for silage was carried out at the milk-dough stage of the plants. After removing the leaves and panicles of the harvested plant samples, the remaining stems were passed through the press machine and the juice was extracted. The bagasse remaining after the juice extraction was shredded into 1.5-2 cm pieces, then filled into 1 litre anaerobic jars and left to fermentation for 60 days under laboratory conditions. At the end of the fermentation period, the jars were opened and the dry matter rate, pH, crude protein, ADF and NDF rates were analysed. According to the two-year average results of the study, significant differences were found among the varieties in terms of quality parameters such as dry matter rate, pH, ADF and NDF rates. The highest dry matter rate (33.77%) and the lowest ADF (36.25%) and NDF (54.03%) rates were obtained from Erdurmuş variety. Increasing nitrogen doses caused an increase only in crude protein content of bagasse silage. In conclusion, in order to obtain a well-balanced bagasse silage in terms of crude protein content and digestibility, it can be recommended to prefer Erdurmuş variety and to use 8 kg/da nitrogen dose.

Keywords: Bagasse, nitrogen, second crop, silage quality, sweet sorghum

İKİNCİ ÜRÜN KOŞULLARINDA YETİŞTİRİLEN BAZI ŞEKER SORGUM ÇEŞİTLERİNDE ARTAN AZOT DOZLARININ POSANIN SİLAJ KALİTESİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışma, Bursa ekolojik koşullarında ikinci ürün olarak yetiştirilen bazı şeker sorgum çeşitlerinde (Gülşeker, Erdurmuş ve Uzun) artan azot dozlarının (0, 8, 16 ve 24 kg/da) posanın silaj kalitesi üzerindeki etkilerini belirlemek amacıyla B.U.Ü. Ziraat Fakültesi TUAM deneme alanlarında 2022 ve 2023 yıllarında yürütülmüştür. Silaj amacıyla bitki hasadı, tanelerin süt-hamur olum döneminde yapılmıştır. Hasat edilen bitki örneklerinin yaprak ve salkımları alındıktan sonra geriye kalan saplar pres makinesinden geçirilmiş ve özsuyu çıkarılmıştır. Özsuyu çıkarıldıktan sonra kalan posa 1.5-2 cm boyutlarında parçalanmış, daha sonra 1 litrelik anaerobik kavanozlara doldurulmuş ve laboratuvar koşullarında 60 gün boyunca fermantasyona bırakılmıştır. Fermantasyon süresi sonunda kavonozlar açılmış ve silajlarda kuru madde oranı, pH değeri, ham protein, ADF ve NDF oranları gibi özellikler incelenmiştir. Araştırmanın iki yıllık ortalama sonuçlarına göre; çeşitler arasında kuru madde oranı, pH değeri, ADF ve NDF oranları gibi kalite parametreleri açısından önemli farklılıklar ortaya çıkmıştır. En yüksek kuru madde oranı (%33.77) ile en düşük ADF (%36.25) ve NDF (%54,03) oranları Erdurmuş çeşidinden elde edilmiştir. Artan azot dozları posa silajının sadece ham protein içeriğinde artışa neden olmuştur. Sonuç olarak, ham protein içeriği ve sindirilebilirlik açısından iyi dengelenmiş bir posa silajı elde etmek için Erdurmuş çeşidinin tercih edilmesi ve 8 kg/da azot dozunun kullanılması önerilebilir.

Anahtar kelimeler: Azot, ikinci ürün, posa, silaj kalitesi, şeker sorgum

Giriş

Şeker sorgumun (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr) toplam kütlesinin %70-75'i saptan, %10-15'i yapraktan, %7'si taneden ve %10'u kökten oluşmaktadır (Sadigfard, 2016).Güçlü ve hızlı büyümesiyle birlikte oldukça etkili bir kök yapısına sahiptir (Demir, 2020). Birçok bitkiye göre daha az su ve gübreye ihtiyaç duymaktadır. Kurak koşullarda dahi gelişimini sürdürebilen bu bitki, geçici kuraklıklara dayanabilme özelliği ile bitkiler aleminin devesi olarak anılmaktadır (Küçüksemerci, 2017). Şeker sorgum sapından elde edilen özsu, tatlandırıcı, şurup, pekmez ve jaggery yapımında kullanılmaktadır (Mathur ve ark., 2017). Şeker sorgumun pres yardımıyla suyu çıkarıldıktan sonra geriye kalan posası, hayvan yemi, kâğıt veya etanol üretiminde değerlendirilebilir (Mosali ve ark., 2010). Ancak, ekonomik nedenlerden dolayı posadan etanol üretimi gelecekte pek umut verici bir seçenek olarak görülmemektedir. Bu nedenle, posanın ruminantlar için potansiyel bir yem kaynağı olarak kullanımı ön plana çıkmaktadır (Naeini ve ark., 2014). Şeker sorgum posası, %27-45 selüloz, %25-30 hemiselüloz ve %11-25 lignin içermektedir. Tarımsal bir yan ürün olan bu posa, katkı maddesi olmaksızın iyi bir silaj kaynağıdır ve hayvan beslenmesinde güvenle kullanılabilir (Kumari ve ark., 2013). Posadan elde edilen silaj, mikro besinler ve mineraller açısından zengin olup, özellikle süt sığırları için besleyici bir yem kaynağıdır (Mathur ve ark., 2017). Değişen çevre koşullarına uygun olarak şeker sorgumun azot ihtiyacının belirlenmesi için farklı azotlu gübre uygulamalarını içeren araştırmalara ihtiyaç vardır (Almodes ve Hadi, 2009). Geniş genetik çeşitlilik ve benzer çevre ile yönetim koşullarına verilen farklı tepkiler, belirli bölgelerdeki verimlilik potansiyellerinin belirlenmesi amacıyla çeşitlerin değerlendirilmesini zorunlu kılmaktadır. Bu nedenle, her bir çeşit ve yetiştirme koşulu için en uygun azot miktarının belirlenmesi, sürdürülebilir tarım uygulamaları açısından gereklidir.

Bu çalışma, Bursa İli'nde ikinci ürün koşullarında yetiştirilen şeker sorgum çeşitlerinde (Gülşeker, Erdurmuş ve Uzun) artan azot dozlarının (0, 8, 16 ve 24 kg/da) posanın silaj kalitesi üzerindeki etkilerini belirlemek amacıyla yürütülmüştür.

Materyal ve Yöntem

Araştırma, 2022 ve 2023 yıllarında Bursa Uludağ Üniversitesi Ziraat Fakültesi TUAM'da tarla denemesi olarak tesadüf bloklarında bölünmüş parseller deneme düzeni'ne göre 3 tekrarlamalı olarak yürütülmüştür. Denemelerde ana parsellere şeker sorgum çeşitleri (Gülşeker, Erdurmuş ve Uzun), alt parsellere ise azot dozları (0, 8, 16 ve 24 kg/da) yerleştirilmiştir.

Araştırmada, her bir alt parselde sıra arası 70 cm olacak şekilde 5 m boyunda sıralar açılmış ve ekim 5 Temmuz 2022 ve 6 Temmuz 2023 tarihlerinde elle yapılmıştır. Denemede hasat bitkilerin süt-hamur olum döneminde yapılmıştır. Hasat döneminde her bir alt parselde, parseli temsil eden 10 adet bitki alınmış ve hasat edilen bitkilerin yaprak ve salkımları alındıktan sonra geride kalan saplar özel tasarlanmış bir makinede preslenmiş ve özsuyu çıkarılmıştır. Özsuyu çıkarıldıktan sonra kalan posa tek sıralı silaj makinesinden geçirilerek 1.5-2 cm boyutlarında parçalanmıştır. Posa silajı yapmak amacıyla parçalanan materyaller torbalara doldurulup etiketlenmiş ve ardından laboratuvara getirilmiştir. Laboratuvara getirilen parçalanmış materyallerin torbaları açılmış ve iyice karıştırıldıktan sonra bir pres yardımıyla 1 litrelik anaerobik kavanozlara sıkıştırılarak doldurulmuş ve etiketlenerek laboratuvar koşullarında 60 gün süreyle fermantasyona bırakılmıştır. 60 günlük fermantasyon dönemi sonunda açılan kavanozların her birinden en az 150 g örnek alınmış ve 70 °C'de 48 saat kurutularak kuru madde oranları belirlenmiştir. Ayrıca, 40 g örnek alınıp 360 ml saf su eklenmiş ve 3 dak. çalkalanmıştır. Çalkalama işlemi tamamlandıktan sonra örnekler süzülmüş ve bu süzüklerde

pH değeri ölçülmüştür (Budaklı Çarpıcı, 2009). Kuru madde oranını belirlemek amacıyla kullanılan örnekler öğütülmüş ve bu örneklerde ham protein oranı, ADF oranı ve NDF oranını belirlemek amacıyla analizler yapılmıştır (AOAC 1990; Van Soest ve ark.,1991).

2022 ve 2023 yıllarında yürütülen denemelerden elde edilen veriler birleştirilmiş ve "Tesadüf Bloklarında Bölünmüş Parseller Deneme Düzeni'ne uygun olarak varyans analizine tabi tutulmuşlardır (Turan, 1995). Bütün hesaplamalar bilgisayarda JMP Pro 13 paket programını kullanarak yapılmıştır. Önemlilik testlerinde %1 ve %5, farklı grupların belirlenmesinde ise %5 olasılık düzeyi kullanılmıştır. Farklı grupların belirlenmesinde Asgari Önemli Fark (AÖF) testinden yararlanılmıştır.

Araştırma ve Bulgular

Araştırmada iki yılın birleştirilmiş verileri üzerinden varyans analizleri yapılmıştır. Varyans analiz sonuçlarına göre; çeşitlerin posa silajının kuru madde oranı, pH değeri ve NDF oranları üzerine etkileri % 1, ADF oranı üzerine etkisi ise %5 olasılık düzeyinde önemli bulunmuştur. Azot dozlarının silajın ham protein oranı üzerine etkisi %1 olasılık düzeyinde önemli olmuştur. Ayrıca çeşit x azot dozu interaksiyonunun kuru madde oranı ve pH değeri üzerine etkisi %5 olasılık düzeyinde önemli bulunmuştur (Çizelge 1).

Çizelge 1. İkinci ürün koşullarında yetiştirilen şeker sorgum çeşitlerinde farklı azot dozlarının posa silajının kalite özelliklerine ilişkin varyans analizi sonuçları (KO)

Varyasyon Kaynağı	SD	KM	pH	HP	ADF	NDF
Yıl (Y)	1	*	*	**	**	**
Çeşit	2	**	**	öd	*	**
Ç X Y	2	öd	öd	öd	öd	**
Azot Dozu	3	öd	öd	**	öd	öd
Y X AD	3	*	*	*	öd	öd
Ç X AD	6	*	*	öd	öd	öd
Y X Ç X AD	6	öd	*	öd	öd	öd

Y: Yıl, Ç:çeşit, AD: azot dozu, SD: Serbestlik derecesi, öd: önemli değil

KM: Kuru madde, HP: Ham protein, ADF: Asit deterjanda çözünmeyen lif, NDF: Nötr deterjanda çözünmeyen lif,

** ,*; Sırasıyla % 1 ve % 5 düzeyinde önemlidir.

Çeşitler bakımından en yüksek kuru madde oranı %33.77 ile Erdurmuş çeşidinden elde edilmiştir (Çizelge 2). Yücel ve ark. (2024) Adana koşullarında şeker sorgum hat ve çeşitlerine ait posa silajının kuru madde oranının %27.33-37.86 arasında değiştiğini bildirmişlerdir. Artan azot dozu uygulamaları, posa silajlarının kuru madde oranını etkilememiş ve ortalama kuru madde oranı %32.27-32.80 arasında değişim göstermiştir.

Araştırmada en düşük pH değeri 3.79 ile Gülşeker çeşidinden, en yüksek ise istatistiksel olarak aynı grupta yer alan Erdurmuş (3.95) ve Uzun (3.90) çeşitlerinden elde edilmiştir (Çizelge 2). Şeker sorgum çeşit/çeşitleri ile yapılan çalışmalarda da oldukça farklı pH değerleri tespit edilmiştir. Örneğin; Yücel ve ark. (2017) Çukurova/Adana koşullarında farklı şeker sorgum

genotiplerine ait posa silajının pH değerinin 3.03-3.20 arasında, Yücel ve ark. (2024) ise şeker sorgum çeşitlerine ait posa silajlarının pH değerleri arasında farklılığın olmadığını ve genel olarak pH değerlerinin 3.02-3.34 arasında değiştiğini bildirmişlerdir. Artan azot dozu uygulamaları posa silajlarının pH değerini etkilememiş ve pH değeri 3.88-3.91 arasında değişim göstermiştir (Çizelge 2).

Çeşitler arasında ham protein oranı bakımından önemli farklılıklar ortaya çıkmamış ve posa silajlarının ham protein oranları %3.05-3.15 arasında değişim göstermiştir (Çizelge 2). Taş ve ark. (2021) Şanlıurfa koşullarında şeker sorgum genotipleri ile yürüttükleri bir çalışmada, ham protein oranı açısından istatistiksel olarak önemli bir fark bulunmadığını ve ham protein oranının %3.40-4.60 arasında değişim gösterdiğini rapor etmişlerdir. Azot dozları bakımından ham protein oranları değerlendirildiğinde, en yüksek ham protein oranının %3.67 ile 24 kg/da azot dozundan elde edildiği belirlenmiştir (Çizelge 2).

Şeker sorgum çeşitlerine ait posa silajının ADF ve NDF oranları incelendiğinde; en düşük ADF (%36.25) ve NDF (%54.03) oranlarının Erdurmuş çeşidinden elde edildiği tespit edilmiştir (Çizelge 2). Taş ve ark. (2021) Şanlıurfa koşullarında yürüttükleri bir çalışmada, şeker sorgum genotipleri arasında ADF ve NDF oranları bakımından farklılıklar gözlenmiş ve ADF oranının %27,33-43,16, NDF oranının ise %47,30-65,30 arasında değişim gösterdiğini bildirmişlerdir. Azot dozlarının posa silajının ADF ve NDF oranları üzerine etkisi istatistiki olarak önemsiz olmuş ve ADF oranları %41.41-43.03, NDF oranları ise %61.00-62.64 arasında değişim göstermiştir (Çizelge 2).

Çeşit x azot dozu interaksiyonu incelendiğinde; çeşitlerin artan azot dozu uygulamalarına karşı gösterdikleri tepki farklılık göstermiş ve posa silajında en yüksek kuru madde oranı Erdurmuş çeşidinin 0 kg/da azot dozu uygulanan parsellerinden elde edilmiş ve bunu oranı Erdurmuş çeşidinin 8 kg/da azot dozu uygulaması takip etmiştir. En düşük kuru madde oranı ise Gülşeker çeşidinin 0 kg/da, 8 kg/da ve 16 kg/da azot dozu uygulamalarından elde edilmiştir.

Çizelge 2. İkinci ürün koşullarında yetiştirilen şeker sorgum çeşitlerinde farklı azot dozlarının posa silajının bazı kalite özellikleri üzerine etkisi (iki yıllık ortalama veriler)

Çeşit	Azot Dozları (kg/da)				Ortalama
	0	8	16	24	
Kuru madde oranı (%)					
Gülşeker	31.81 c-e	30.88 e	30.78 e	32.07 c-e	**31.39 B**
Erdurmuş	34.73 a	34.53 ab	32.88 cd	32.93 cd	**33.77 A**
Uzun	31.86 c-e	31.43 de	33.13 bc	32.28 c-e	**32.18 B**
Ortalama	**32.80**	**32.28**	**32.27**	**32.43**	
pH					
Gülşeker	3.76 e	3.79 e	3.79 e	3.82 de	**3.79 B**
Erdurmuş	3.98 a	3.98 a	3.90 bc	3.93 a-c	**3.95 A**
Uzun	3.89 c	3.88 cd	3.88 cd	3.97 ab	**3.90 A**
Ortalama	**3.88**	**3.88**	**3.89**	**3.91**	
Ham protein oranı (%)					
Gülşeker	2.96	2.74	3.02	3.49	**3.05**
Erdurmuş	2.70	3.08	3.27	3.55	**3.15**
Uzun	2.77	2.73	3.11	3.97	**3.14**
Ortalama	**2.81 C**	**2.85 BC**	**3.13 B**	**3.67 A**	
ADF (%)					
Gülşeker	45.26	43.92	45.68	44.19	**44.76 A**
Erdurmuş	36.70	37.54	35.97	34.76	**36.25 B**
Uzun	46.41	45.69	47.42	45.28	**46.20 A**
Ortalama	**42.79**	**42.38**	**43.03**	**41.41**	
NDF (%)					
Gülşeker	64.18	64.39	64.90	64.34	**64.45 B**
Erdurmuş	55.34	55.99	52.69	52.08	**54.03 C**
Uzun	68.40	65.95	68.95	66.56	**67.47 A**
Ortalama	**62.64**	**62.11**	**62.18**	**61.00**	

Yıl, çeşit, azot dozu ve çeşit x azot dozu interaksiyonuna ait önemli çıkan ortalamalarda aynı harfi taşıyan değerler arasında 0.05 olasılık düzeyinde fark yoktur.

Sonuç ve Öneriler

Posa silajının yem kalitesini belirlemek amacıyla yapılan çalışmada; Erdurmuş çeşidi en yüksek kuru madde oranını sağlamıştır. Ayrıca, Erdurmuş çeşidinin en düşük ADF ve NDF oranlarına sahip olması, posa silajının sindirilebilirliğini artırarak hayvan besleme açısından daha yüksek enerji verimliliği sağlamaktadır. Azot dozlarının posa silaj kalitesi üzerindeki etkileri, özellikle ham protein oranı açısından istatistiksel olarak önemli bulunmuştur. Artan azot dozları ham protein oranını artırmış ve en yüksek ham protein oranı 24 kg N/da uygulamasında tespit

edilmiştir. Ancak, artış gösteren azot dozlarının kuru madde oranı, pH değeri, ADF ve NDF oranları üzerinde istatistiksel olarak önemli bir etkisi tespit edilmemiştir. Çeşit x azot dozu interakasiyonu açısından da en yüksek kuru madde oranı Erdurmuş çeşidinin 0 kg/da azot dozu uygulanan parsellerinden elde edilmiş ve bunu oranı Erdurmuş çeşidinin 8 kg/da azot dozu uygulaması takip etmiştir. Çevresel sürdürülebilirlik ve ekonomik faktörler göz önünde bulundurulduğunda, posa silajında sindirilebilirliği ve kaliteyi dengelemek için Erdurmuş çeşidinin tercih edilmesi ve 8 kg/da azot dozunun kullanılması önerilmektedir.

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DISASTER RESPONSE AND EMERGENCY MEDICAL SERVICES: CHALLENGES AND SOLUTIONS

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ABSTRACT

Natural disasters—including earthquakes, hurricanes, floods, and wildfires present complex and multifaceted challenges to emergency medical services (EMS) and disaster response teams. These events often occur with little to no warning, leading to widespread disruption of infrastructure, mass casualties, and overwhelming demands on health care resources. This paper aims to explore the critical challenges encountered in emergency medical response during such disasters and to propose strategic solutions to enhance the overall effectiveness and efficiency of interventions. Based on a comprehensive review of recent literature, several recurring issues have been identified that significantly hinder timely and effective response efforts. Among the most prominent are breakdowns in communication systems, which can isolate response teams and delay the coordination of aid; severe transportation difficulties resulting from damaged roads, bridges, or traffic congestion; acute shortages of trained medical personnel in affected areas; and insufficient availability of medical supplies and equipment needed for immediate care. These factors can collectively reduce the speed, accuracy, and quality of emergency services when they are needed most. In addition to analyzing these operational barriers, this study underscores the vital importance of pre-disaster preparedness strategies. These include regular simulation exercises, community education initiatives, the development of comprehensive disaster response plans, and the establishment of emergency stockpiles. The integration of advanced technologies such as real-time communication tools, artificial intelligence for triage and resource allocation, and Geographic Information Systems (GIS) for situational awareness is also explored as a means of strengthening disaster response capabilities. Furthermore, the research emphasizes the necessity of multidisciplinary coordination among healthcare providers, emergency responders, governmental bodies, non-governmental organizations, and community leaders. Such collaboration ensures that all aspects of disaster response from initial rescue efforts to long-term recovery are effectively managed. In conclusion, this paper highlights the crucial role of proactive planning, technological innovation, and interagency cooperation in building resilient EMS systems capable of withstanding the complex demands of natural disasters.

Keywords: Artificial Intelligence, Disaster Response, Emergency Medical Services, Mental Health

Introduction

Natural disasters including but not limited to earthquakes, hurricanes, floods, and wildfirescontinue to pose substantial and multifaceted challenges to emergency medical services (EMS) and disaster response teams worldwide. These unpredictable and often rapidly evolving events typically result in widespread human casualties, extensive physical and infrastructural damage, and the disruption of essential services such as communication networks and transportation systems. Such disruptions can severely hinder the capacity of EMS teams to provide timely, organized, and effective medical assistance to affected populations (Smith et al., 2021).

One of the most pressing challenges during natural disasters is the sudden and overwhelming surge in demand for medical care, which frequently exceeds the available resources and capabilities of local healthcare systems. Hospitals may become overcrowded or entirely inaccessible, roads and bridges may be blocked or destroyed, and emergency personnel may be limited in number or unable to reach critical areas due to safety concerns or logistical constraints. Moreover, the coordination between various emergency agencies is often complicated by communication breakdowns, lack of standardized protocols, and unclear chains of command, all of which contribute to delays and inefficiencies in rescue and medical operations. Given these complex conditions, it is essential to identify the specific obstacles faced by EMS teams in natural disaster scenarios and to develop effective, scalable strategies that enhance disaster preparedness and response. This paper aims to examine the primary challenges namely communication failures, logistical limitations, staffing shortages, and equipment deficits and to propose evidence-based solutions. These include improved pre-disaster planning, the integration of emerging technologies, enhanced interagency collaboration, and the implementation of targeted training programs to bolster readiness for mass casualty incidents (Smith et al., 2021). Through a critical review of current literature and illustrative case studies, this study seeks to contribute to the development of a more resilient and adaptive emergency medical framework one that can respond rapidly and effectively to the growing frequency and severity of natural disasters around the world..

Challenges in Disaster Response and EMS

Disaster response operations, particularly those involving emergency medical services (EMS), are frequently obstructed by a series of interrelated challenges that can severely impair the effectiveness and timeliness of interventions. One of the most critical issues is the breakdown of communication networks during natural disasters. When mobile networks, internet connections, and radio communication systems are disrupted or destroyed, the ability of various emergency units to coordinate becomes significantly diminished. This lack of communication not only delays the mobilization of resources but also results in confusion, overlapping efforts, or critical gaps in care delivery (Johnson & Lee, 2022).

Another substantial obstacle is the widespread damage to transportation infrastructure. Earthquakes, floods, and hurricanes can destroy roads, bridges, and railways, rendering many affected regions inaccessible. As a result, the transportation of emergency personnel, medical supplies, and patients becomes logistically complicated and time-consuming. Delays in reaching disaster-stricken zones may lead to preventable fatalities and prolonged suffering for those with critical injuries or medical conditions (Kumar et al., 2020).

Staffing shortages during large-scale disasters further compound the difficulties faced by EMS teams. In many cases, local healthcare personnel may themselves be victims of the disaster or unable to reach their workplaces due to personal losses or infrastructural barriers.

Simultaneously, the sudden and overwhelming influx of patients often with complex trauma cases can rapidly exceed the treatment capacity of available responders. The physical and psychological toll on medical staff in such high-pressure, high-volume environments cannot be underestimated (Rodriguez et al., 2023).

Equally problematic is the lack of sufficient medical equipment and supplies in disaster zones. First responders may operate with limited access to essential tools such as trauma kits, ventilators, stretchers, and medications. This scarcity can degrade the quality and scope of care that can be provided on-site or during transport. Replenishment of supplies is often delayed due to damaged infrastructure, logistical complications, or inadequate pre-disaster planning (Nguyen & Patel, 2021).

Collectively, these challenges highlight the fragility of EMS systems in the face of large-scale emergencies and underscore the urgent need for robust contingency planning, resource stockpiling, and infrastructure resilience. Addressing these systemic weaknesses is vital for ensuring that emergency medical care remains effective and equitable under disaster conditions (Johnson & Lee, 2022; Kumar et al., 2020; Rodriguez et al., 2023; Nguyen & Patel, 2021).

Proposed Solutions and Innovations

In response to the multifaceted challenges that arise during natural disasters, numerous innovative strategies and solutions have been proposed to strengthen the effectiveness and resilience of emergency medical services (EMS). Addressing communication breakdowns is a top priority, as the ability to coordinate efforts and allocate resources hinges on uninterrupted information exchange. One of the most effective approaches involves the integration of resilient satellite communication systems, which can function independently of terrestrial infrastructure and provide reliable connectivity even when local networks are compromised. These systems allow for real-time coordination between emergency units, centralized command centers, and on-site personnel, thereby improving overall response efficiency (Ahmed et al., 2024).

Transportation logistics during disasters can be improved through both proactive planning and technological innovation. Establishing pre-designated emergency routes that are routinely maintained and clearly marked can facilitate quicker access to affected zones. In addition, the use of unmanned aerial vehicles (UAVs), commonly known as drones, has emerged as a transformative tool in disaster medicine. Drones can be deployed rapidly to deliver essential medical supplies, such as blood products, medications, or defibrillators, to hard-to-reach or isolated areas. Their speed, mobility, and ability to bypass ground-level obstacles make them particularly valuable during the critical early stages of disaster response (Wang & Garcia, 2023).

To address personnel shortages, expanding the EMS workforce through targeted volunteer training programs is essential. Community-based disaster preparedness initiatives can empower local residents with basic emergency response skills, ensuring that initial life-saving care can begin even before professional responders arrive. Furthermore, fostering inter-agency cooperation among fire departments, military units, non-governmental organizations (NGOs), and healthcare facilities can help pool resources and personnel, enhancing the system’s overall surge capacity during crises (Lopez et al., 2022).

Another crucial area of advancement lies in the development and deployment of portable, durable, and multifunctional medical equipment specifically designed for use in disaster environments. Compact diagnostic tools, field-deployable ventilators, solar-powered monitoring devices, and modular treatment stations are just a few examples of innovations that can significantly improve patient outcomes in austere conditions. These technologies not only

allow for rapid and high-quality interventions in the field but also reduce the burden on overwhelmed hospitals and facilitate more effective triage and stabilization (Chen & Smith, 2023).

In summary, a combination of cutting-edge technology, proactive logistical planning, community engagement, and cross-sector collaboration offers a comprehensive framework for enhancing EMS performance during natural disasters. Implementing these solutions not only mitigates the immediate impact of such events but also builds long-term resilience within health and emergency response systems (Ahmed et al., 2024; Wang & Garcia, 2023; Lopez et al., 2022; Chen & Smith, 2023).

Case Studies

Real-world disaster scenarios provide invaluable insights into the strengths and weaknesses of emergency medical service (EMS) responses, as well as the effectiveness of innovative strategies under extreme conditions. Several recent disasters serve as compelling case studies that underscore the critical role of coordination, adaptability, and technological integration in mitigating the human toll of natural catastrophes.

The response to the 2020 Australian bushfires is a notable example of how coordinated EMS operations and swift resource mobilization can significantly reduce disaster impact. The scale and intensity of the fires overwhelmed many rural and semi-urban communities, yet the rapid deployment of mobile medical units, air ambulances, and volunteer responders helped bridge the gap in healthcare access. A key factor in the effectiveness of this response was the seamless collaboration among local EMS units, national emergency agencies, and international humanitarian organizations. This multilevel cooperation enabled timely triage, evacuation, and treatment of burn victims and respiratory patients. The use of mobile clinics to deliver care directly within fire-affected zones reduced reliance on distant hospitals and improved health outcomes for isolated populations (Brown et al., 2021).

A different but equally informative case is the 2022 Pakistan floods, where vast geographical barriers and inaccessible terrains created major logistical challenges for EMS teams. Here, the use of drone technology proved transformative. Drones were deployed to deliver life-saving medications and water purification tablets to remote communities cut off by floodwaters. EMS personnel also employed amphibious vehicles to reach stranded residents and set up temporary health stations in high-need areas. These adaptive responses not only ensured continuity of care but also played a key role in curbing the spread of waterborne diseases such as cholera and dysentery. This case illustrates how integrating local knowledge with modern tools can dramatically enhance disaster response capabilities in regions with difficult topography (Ali et al., 2023).

Another instructive case is the international medical response following the 2015 Nepal earthquake, which resulted in over 9,000 deaths and left tens of thousands injured. The local EMS system, already limited in capacity, was quickly overwhelmed by the sheer scale of the disaster. International support became essential. Medical and rescue teams from multiple countries including India, China, the United States, and the European Union arrived within days to provide emergency trauma care, perform search and rescue operations, and assist in setting up temporary medical infrastructure. Coordination was facilitated through the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), which helped standardize logistics, prioritize aid delivery, and reduce redundancies. This case underscores the vital

importance of pre-established international protocols, shared terminology, and interoperable equipment in large-scale emergencies (UN OCHA, 2016).

Collectively, these case studies highlight the necessity of flexible, scalable, and well-coordinated EMS systems in disaster scenarios. They emphasize how technological tools like drones and air ambulances, when combined with effective inter-agency and international collaboration, can significantly reduce morbidity and mortality in crisis situations. Furthermore, they offer practical models for disaster preparedness and response that other regions and nations can adapt according to their unique geographic and infrastructural challenges.

Conclusion and Recommendations

An effective response to natural disasters demands a comprehensive, multi-disciplinary strategy that harmonizes communication technology, logistical coordination, and human resource management. These elements must function in unison under high-pressure conditions to ensure that emergency medical services (EMS) can provide rapid and life-saving interventions. One of the key findings in disaster medicine literature is the importance of proactive investment in both technological and infrastructural resilience before disasters occur. This pre-emptive approach significantly reduces response times and enhances the capacity of EMS systems to adapt to dynamic and chaotic environments (Miller et al., 2024).

Among the foundational components of preparedness are the establishment of well-equipped emergency operations centers (EOCs), the systematic stockpiling of essential medical supplies, and the execution of localized hazard risk assessments. These efforts enable decision-makers to anticipate potential vulnerabilities and allocate resources effectively. EOCs serve as command hubs where data is analyzed, strategies are coordinated, and logistics are streamlined critical for maintaining order and continuity during crises.

In parallel, workforce readiness is vital. Regular and structured training initiatives, including simulation-based exercises, are necessary to ensure that EMS personnel remain competent and responsive in unpredictable disaster scenarios. These drills not only reinforce individual skills but also strengthen team dynamics and decision-making under stress. Furthermore, inter-agency drills involving healthcare services, fire and rescue units, law enforcement, military personnel, and non-governmental organizations foster unity of effort under a common operational framework (Singh & Kumar, 2022). Such cooperation minimizes delays caused by fragmented response efforts and promotes clarity in roles and responsibilities.

The discussion also emphasizes the importance of community involvement as a critical, yet often underutilized, asset in disaster response. Public education campaigns, civilian first aid training, and grassroots awareness initiatives can transform ordinary citizens into capable first responders, particularly in rural or overwhelmed urban zones. In many cases, bystanders are the first individuals on scene, and equipping them with basic life-saving knowledge can significantly improve survival outcomes before professional help arrives (Chen & Smith, 2023).

Another important consideration is hospital-level preparedness. Hospitals must embed a culture of readiness by developing and regularly updating contingency plans, conducting internal drills, and ensuring flexible resource allocation. This includes the availability of surge capacity plans, backup power systems, mobile treatment units, and designated triage zones. Such institutional readiness is key to preserving healthcare continuity during large-scale disasters. Finally, policy-level commitment is crucial to sustaining long-term preparedness. Policymakers must recognize that emergency health response is not merely a public health issue but a matter of national security. Accordingly, it requires sustained and prioritized funding. Dedicated budgets for disaster preparedness, infrastructure reinforcement, and emergency training programs can

prevent system failures and reduce the economic and human costs of disasters. In addition, collaborative research initiatives that unite academia, government, and the private sector can lead to the development of innovative tools, evidence-based protocols, and scalable best practices that support frontline responders in real time. In summary, a robust disaster response system is one that is holistic, forward-thinking, and inclusive leveraging technology, training, policy, and public engagement to build resilience at every level of society.

Natural disasters continue to pose complex, high-stakes challenges for emergency medical services (EMS) and disaster response systems around the world. The unpredictable nature and wide-ranging impact of such events demand not only rapid action but also carefully planned, adaptable, and resource-conscious strategies. This study has highlighted the critical areas where current disaster response efforts often fall short namely communication failures, transportation obstacles, personnel shortages, and limited access to essential medical equipment. Each of these issues has a direct effect on the speed and quality of emergency care provided during crisis situations. Addressing these challenges requires a forward-thinking and multi-layered approach. Strengthening communication infrastructure through the use of satellite-based systems, improving access routes and employing technologies like drones, expanding the healthcare workforce through community-based training, and investing in portable, durable medical equipment are all key components of an effective response framework. Moreover, a culture of preparedness, both at the institutional and community levels, is essential to ensuring that EMS systems are not only reactive but also proactively equipped to deal with disaster scenarios. Looking ahead, future research and policy development should prioritize the integration of advanced technologies such as artificial intelligence, predictive analytics, and geographic information systems (GIS) to improve situational awareness and real-time decision-making. Additionally, building more cohesive and collaborative inter-agency networks will be crucial to improving operational efficiency and minimizing redundancy or miscommunication during emergencies. Ultimately, the ability to save lives during natural disasters hinges on the capacity of EMS systems to anticipate, adapt, and act. This requires sustained investment, political will, public engagement, and scientific innovation. By embracing these priorities, health systems can transform disaster response from a reactive endeavor into a resilient, coordinated, and life-saving operation.

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EXAMINING THE IMPACTS OF ARTIFICIAL INTELLIGENCE ON THE LABOR MARKET

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ABSTRACT

In recent years, Artificial Intelligence (AI) technologies have been rapidly developing in many sectors and are expected to lead to significant transformations in the labor market. The impacts of AI on the workforce are determined by many factors that, according to different studies, can be shaped in both positive and negative ways. In particular, it is predicted to create major changes in repetitive tasks. With increasing automation, people who make their living from this type of work are likely to face the risk of job loss. On the other hand, it is estimated that AI will create new job opportunities in areas that require creative thinking and strategic skills. It is stated that new employment opportunities may emerge in areas such as health, engineering and creative sectors where skills based on human intelligence come to the fore. The spread of AI may also affect the economic and social structure of society. This transformation will require the reshaping of education systems and workforce development policies. It is of great importance for employees to increase their competencies in order to adapt to developing AI technologies. At this point, it has become a critical requirement for policymakers to develop appropriate strategies to minimize the potential negative impacts of AI. In conclusion, while AI can create significant opportunities in the labor market, it also brings some challenges. Balancing these opportunities and challenges to manage future workforce dynamics is of great importance for both individuals and societies. This study examined the potential impacts of AI on the labor market and assessed the sectoral implications of these impacts. The most important finding of the study is that AI will increase the need for qualified personnel in almost every sector.

Keywords: Artificial Intelligence, labor market, automation, skill mismatch, education policies

Introduction

Artificial intelligence (AI), one of the most striking technological advances of the twenty-first century, is radically transforming the lifestyles of individuals, the way organizations do business, and the general interaction patterns of societies. Thanks to rapid developments in the fields of big data, machine learning and algorithms, artificial intelligence has become a strategic element that directly affects economic systems, production processes and social structures (Brynjolfsson & McAfee, 2014). One of the areas where this transformation is felt most clearly is the labor market. AI's capacity to take over repetitive and systematic tasks poses a serious employment risk for low-skilled workers, while also paving the way for the emergence of new occupational groups in creative and strategic fields based on human-centered competencies (Chui et al., 2016). The effects of artificial intelligence on the labor force are too multidimensional to be explained solely by technological change. The fact that automation occurs at different intensities on a sectoral basis causes the risk of job loss and occupational transformation processes to vary according to the sector (Frey & Osborne, 2017). For example, while the impact of automation is felt harder and faster in areas such as industry, production and logistics, AI is positioned more as a supportive auxiliary tool in health, education and creative industries. However, these overarching effects of AI are forcing not only individuals but also countries to transform their economic plans, education policies and social security systems (OECD, 2022). Recent research indicates that rather than directly increasing unemployment, AI is changing the nature of work and increasing the need for workers with higher skill levels (World Economic Forum, 2023). In this framework, AI-driven transformation poses both risks and opportunities, and who, how and to what extent can adapt to the process is of great importance. At this point, accurate analysis of the effects of AI on the labor market plays a critical role not only in terms of academic research but also in terms of sustainable development goals, social welfare and reducing economic inequalities.

The aim of this study is to examine the effects of artificial intelligence technologies on the labor market from a holistic perspective. By analyzing the effects of AI in different sectors, the study will evaluate occupational groups at risk of job loss, emerging new job areas, the adaptation processes of employees to this transformation, the necessity of restructuring the education system and strategic recommendations for policy makers. Thus, it is aimed to contribute to a more fair, balanced and inclusive management of the new labor order shaped by AI.

Materials and Methods

This study uses descriptive and comparative analysis methods to examine the effects of artificial intelligence technologies on the labor market. Within the scope of the literature review, the reports of OECD, World Economic Forum, McKinsey and similar organizations between 2017 and 2024 were examined. In addition, academic articles on the subject were reviewed and the sectoral impacts of artificial intelligence, transformation in workforce skills and policy recommendations were analyzed. The data were subjected to content analysis and classified in terms of sectoral distinctions and socioeconomic impacts.

Results and Discussion

Artificial intelligence and automation technologies are leading to significant changes, especially in jobs involving repetitive and routine tasks. According to McKinsey & Company's 2023 report, 375 million jobs could be lost worldwide by 2030 due to the impact of automation (McKinsey & Company, 2023). This is particularly evident in sectors such as manufacturing, logistics and customer service. Low-skilled workers in particular are more susceptible to the negative effects of automation, increasing income inequality (Drydakis, 2023). Automation is

the process of partial or complete substitution of human labor through machines, algorithms and software. Artificial intelligence (AI)-assisted automation refers to the use of systems that can perform not only physical tasks but also cognitive tasks. In this context, automation affects not only blue-collar workers but also white-collar workers (Frey & Osborne, 2017). For example, it was reported that Amazon was able to maintain its warehouse operations with 25% fewer people thanks to robotic systems (Chui et al., 2016).

Frey and Osborne (2017) report that 47% of US jobs are at high risk of automation. McKinsey (2023) predicts that 375 million jobs worldwide could disappear by 2030 due to automation. According to OECD (2023), 33% of jobs in Turkey are at high risk of automation. Automation not only leads to job losses, but also changes the nature of the jobs that remain. As simple tasks are automated, workers are expected to perform more complex tasks that require analytical and social skills. This means a significant transformation in the nature of work (World Economic Forum, 2020).

With the development of artificial intelligence technologies, it is predicted that not only simple tasks but also complex tasks such as decision making can be automated in the future. In particular, natural language processing technologies such as ChatGPT are transforming areas such as content production, customer support and consultancy. Therefore, automation threatens not only "physical" jobs but also "cognitive" jobs (Brynjolfsson & McAfee, 2014).

The development of artificial intelligence technologies also enables the emergence of new professions. According to the World Economic Forum's 2024 report, AI and automation are expected to create 97 million new jobs by 2025 (World Economic Forum, 2024). Among these new jobs, roles such as data scientist, AI ethicist, machine learning engineer and robotics technician stand out. Moreover, Micha Kaufman, CEO of Fiverr, emphasizes that professionals who use AI effectively will become more valuable (Business Insider, 2025). Artificial intelligence (AI) is not only causing losses through the automation of existing jobs, but also creating new job fields and professions. This transformation can be explained by the concept of "creative destruction"; old jobs are being replaced by new jobs centered around technological skills and innovative services (Schumpeter, 1942; Brynjolfsson & McAfee, 2014).

With the development of AI, new professions such as artificial intelligence engineering, machine learning expertise, data science and big data analyst, artificial intelligence ethics consultancy, robotic process automation expertise have started to emerge. In addition, some traditional professions are being transformed by the impact of AI. For example:

- Doctors and radiologists are starting to work with AI-enabled diagnostic systems.
- Legal professionals use artificial intelligence for document analysis and contract interpretation.
- Teachers make education more effective with personalized learning software.

This transformation gives rise to the concept of "augmented professions" where humans work alongside AI (Davenport & Ronanki, 2018). The World Economic Forum (2024) stated that 97 million new job positions will emerge thanks to artificial intelligence and digitalization. McKinsey Global Institute (2023) predicts that new jobs created during the technological transformation process can compensate for 85% of lost jobs. According to LinkedIn Economic Graph (2022), the title of "AI expert" has been among the fastest growing job titles in the last 5 years.

AI is also transforming the skills required in the labor market. According to the OECD's 2023 report, both technical and soft skills are required to develop and implement AI systems (OECD,

2023). In particular, skills such as digital literacy, teamwork, problem solving and leadership are coming to the fore. Moreover, employers are increasingly hiring on a skills-driven basis; for example, in the UK, the requirement for a university degree for AI positions has decreased by 15% (Bone, Ehlinger & Stephany, 2023). Artificial intelligence (AI) is not only transforming jobs, it is also radically changing the skills required of individuals to do those jobs. As automation and digitalization enable machines to perform repetitive manual and cognitive tasks, human labor is shifting more towards cognitive, social and creative areas (Brynjolfsson & McAfee, 2014).

To design, implement and oversee AI systems, the digital literacy of the workforce must increase. Software development and programming languages Data analytics and big data management Machine learning and algorithm knowledge AI ethics and data security awareness are some of the technical skills expected from the next generation of workers. However, one-off trainings are not enough to adapt to the skills transformation brought by AI. Instead, a career approach based on continuous learning should be adopted (UNESCO, 2021). According to OECD data, 46% of the workforce will have to update their skills within five years (OECD, 2023). In this context, current education systems are struggling to keep up with this transformation. Artificial intelligence and data science-based courses should be added to curricula, skills-based certificate programs should be expanded, practical experience and project-based learning should be supported, and ethics, communication and leadership skills should be emphasized. Increasingly, companies are adopting hiring practices based on skills rather than diplomas. Bone, Ehlinger and Stephany (2023) report that the diploma requirement for AI positions in the UK has decreased by 15% in the last five years. This shows that individual competencies and learning potential are becoming more prominent.

Artificial intelligence is an important factor affecting income distribution. Workers with AI skills earn on average between 11% and 23% higher salaries (OECD, 2023). However, job security for low-skilled workers is decreasing and income inequality is increasing. Women and low-income groups are particularly vulnerable to the negative impacts of AI (Drydakis, 2023). The proliferation of artificial intelligence (AI) technologies is leading to structural changes that may lead to increased income inequalities. This shift favors highly skilled and technologically adept workers, while threatening the job security and income levels of low-skilled workers (Acemoglu & Restrepo, 2019). By reshaping economic returns, AI allows companies and individuals who develop and use technology to earn more income, while other segments are negatively affected by this transformation.

AI technologies add more value to highly skilled workers. According to the OECD (2023) report, the wage gap is directly proportional to workers' experience of working with AI, level of education and technical competence. This difference is known as the "skills premium" and can lead to greater inequalities over time.

The automation effect of AI reduces job security in low- and medium-skill jobs. Frey and Osborne (2017) note that jobs at high risk of automation are mostly concentrated in low-paying occupations. Women and minorities are also more at risk as they often work in sectors that are more vulnerable to automation (Drydakis, 2023). The shift to temporary, part-time or project-based employment undermines the classic "full-time and permanent" job model. These changes in income and job security can also lead to ruptures in the social structure:

- A shrinking middle class increases economic polarization.
- Youth unemployment is becoming a serious problem, especially in developing countries.

- Social security systems may be inadequate in the AI era as they are structured according to traditional employment models (ILO, 2021).

Education systems should be restructured to adapt to the requirements of the AI era. OECD emphasizes that education policies need to be strengthened for the development of AI skills (OECD, 2023). Moreover, increasing skills-driven recruitment reduces the value of traditional diplomas and increases the importance of alternative educational pathways (Bone, Ehlinger & Stephany, 2023). The rapid development of artificial intelligence (AI) technologies necessitates radical changes not only in job descriptions but also in the structure of education systems. This transformation in the labor market requires individuals to acquire and update skills not only at the beginning but also throughout life (OECD, 2023). In the main areas where AI affects the workforce (production, customer services, data analysis, etc.), some professions are disappearing while new job fields are emerging. In this transition process, individuals need to acquire new skills in order to move from their current jobs to different positions. McKinsey & Company (2023) stated that approximately 100 million of the global workforce will need to be reskilled due to AI. The World Economic Forum (2020) predicts that 50% of the workforce will need retraining by 2025. Governments must play strategic roles to increase access to education and reduce inequalities in the AI era. Support such as incentives, grants, employer-state cooperation and open access resources should be provided by governments. The private sector also has important roles to play. In particular, technology companies are developing internal training programs for their employees to adapt to transforming job descriptions. Companies such as Amazon and Google provide AI and cloud technologies training for their employees. This also ensures labor retention and increased productivity (McKinsey, 2023).

The effects of artificial intelligence (AI) technologies on the workforce vary across sectors. In some sectors, AI transforms business processes to a great extent by putting automation at the center, while in others it functions more as a supportive and complementary tool. This difference stems from the diversity in the technological infrastructure, business structure and employee profile of each sector. Therefore, the impacts of AI at the sectoral level need to be examined in both direct and indirect dimensions (Chui, Manyika & Miremadi, 2016; OECD, 2022). With the spread of the Industry 4.0 vision, AI is leading to radical changes in production processes. Smart production lines equipped with automated systems, robotic solutions and data-driven decision support systems are increasing productivity and reducing the need for manpower, especially in repetitive physical tasks (McKinsey Global Institute, 2017). The effectiveness of AI systems is increasing in areas such as quality control, predictive maintenance, and process optimization, leading to a decrease in low-skilled jobs and an increase in the need for workers with advanced technology knowledge (Frey & Osborne, 2017).

The healthcare sector stands out as one of the areas where AI plays the most supportive role. AI is actively used in applications such as analyzing medical images, early diagnosis of diseases, personalized treatment recommendations and remote health services. For example, it is seen that AI-based systems have reached similar accuracy levels with expert physicians in areas such as cancer detection in radiological images (Topol, 2019). However, areas such as communication between patient and physician, ethical decision-making processes, and emotional support still rely on the human factor, which necessitates human-machine collaboration in the sector (Brynjolfsson & McAfee, 2014). In the field of education, AI plays an important role in the development of personalized learning experiences. Individualized learning paths are offered through data analysis based on student performance, enabling teachers to provide more effective student-specific interventions (UNESCO, 2021). In addition, applications such as language learning, virtual tutors, adaptive testing and automatic grading

systems are becoming widespread in education. However, in order to use these technologies effectively, it is important to develop teachers' digital literacy skills and reshape education policies in this direction (OECD, 2022).

The financial sector is one of the areas where AI has been adopted most rapidly and widely. Applications such as credit risk analysis, fraud detection, automated investment recommendations and customer behavior prediction can be performed faster and more effectively with AI (Binns, 2018). In addition, chat bots and automated call systems used in customer service reduce operational costs and improve service quality. However, the fact that these systems are not transparent in their decision-making processes and are designed in a way that can create potential discrimination raises the need for new regulations at both ethical and legal levels (World Economic Forum, 2023). AI technologies have also begun to have an impact on areas traditionally considered to be the domain of human creativity, such as art, design and media. AI-enabled tools are used in creative processes such as visual arts, music composition, literary text production and graphic design, making content production faster and more accessible. AI systems capable of generating text and images (e.g. GPT and DALL-E) are changing the ways of production in these sectors. However, these developments also raise new ethical and legal debates on issues such as originality, copyright and the nature of art (Acemoglu & Restrepo, 2020). Although creativity is not completely monopolized by humans, a new era is entering in which technology plays a role as a co-producer.

The effects of artificial intelligence technologies on the labor market are not limited to economic productivity and sectoral transformation. This technological progress also leads to serious changes in social structures. From income inequality to digital inequality, from the transformation of public policies to ethical and legal regulations, it brings new debates in many areas. The increasing prevalence of AI across society necessitates not only technological adaptation but also the reconstruction of the socioeconomic order (Acemoglu & Restrepo, 2020; Binns, 2018). The effects of AI-based automation systems on the labor force affect different income and skill groups in different ways. While highly skilled individuals often benefit from this transformation, job security for low-skilled and routine workers is significantly weakened. This risks further deepening social injustice, especially for low-income groups (Frey & Osborne, 2017). Acemoglu and Restrepo (2020) argue that while technological advances have increased productivity and raised the incomes of capital owners, they have also led to a reduction in the real income of many workers. Such an income gap can reinforce perceptions of social polarization, insecurity and economic injustice. Therefore, a more equitable sharing of technology-induced prosperity is important for a sustainable social balance.

A healthy transformation based on AI depends on individuals and organizations having access to these technologies. However, opportunities to access technology are not equal across all segments of society. Especially those living in rural areas, low-income individuals and groups with limited digital literacy are in danger of being left out of this transformation process (UNESCO, 2021). This situation reveals structural inequalities, the so-called digital divide. This imbalance in access to information, education and technological opportunities also limits access to socioeconomic opportunities. According to OECD (2022), in order to eliminate this gap, it is necessary to expand digital infrastructure, develop inclusive education policies and increase technological literacy.

The transformations created by artificial intelligence in social and economic life necessitate the reshaping of public policies. It is important for the state to play a role not only as a regulator but also as a transformative and supportive actor. In particular, vocational training programs, skill updating processes and lifelong learning policies should be encouraged for the workforce

to adapt to this new structure (World Economic Forum, 2023). However, it is of great importance to establish an ethical and legal framework to ensure that AI systems operate in a fair, transparent and accountable manner. Binns (2018) emphasizes that algorithmic decision-making systems should be structured in line with the principles of explainability, auditability and responsibility in order not to undermine social trust. Governance processes should also be reconstructed in the light of these ethical principles.

The transformation that artificial intelligence technologies will create in the labor market will not only be limited to the lines of work, but will also reshape the education levels, skill sets and learning styles of individuals who will take part in these jobs. A successful career journey will be possible not only by having technical knowledge, but also by raising individuals who can adapt to change by showing flexibility and adopt a lifelong learning approach (OECD, 2022). In this context, the transformation of education systems and the process of upskilling employees and developing new skills is of critical importance. Traditional education systems are generally shaped around specific occupational groups and narrow areas of knowledge. However, the professions that stand out in the age of artificial intelligence exhibit a multidisciplinary structure and meet rapidly changing knowledge requirements. Therefore, education systems need to be restructured to provide skills such as analytical thinking, problem solving, digital literacy, data literacy and algorithmic thinking (World Economic Forum, 2023). According to the OECD (2022) report, not only technical skills but also "human" skills such as communication, collaboration, ethical judgment and creativity are critical for success in AI-enabled work environments. Accordingly, teachers need to adapt to digital technologies and participate in continuous professional development programs (UNESCO, 2021).

In the light of artificial intelligence and other digital technologies, it is no longer sufficient for individuals to pursue their careers only with the education they received at a young age. In a rapidly changing business world, individuals are expected to continuously update themselves, acquire new skills and adapt to sectoral changes (Brynjolfsson & McAfee, 2014). In this context, the dissemination of lifelong learning has become an extremely important necessity. The World Economic Forum (2023) points out that 50% of workers will have to acquire new skills in the next five years. Accordingly, both the government and the private sector need to invest in training and skills development programs. Short-term certificate programs, online training platforms and on-the-job training stand out as effective tools in this process.

Education policies that comprehensively address the impacts of AI and technology should be shaped not only at the individual level but also at the societal scale. States are obliged to provide equal educational opportunities to all their citizens and programs should be developed especially for low-income and disadvantaged groups (OECD, 2022). At the same time, the business world should not only utilize its workforce but also develop corporate social responsibility projects to contribute to the development of its employees (Binns, 2018). Education and skills development processes should be seen as an important factor that supports not only economic but also social cohesion and social solidarity. Every investment in a skilled workforce is an important step towards a sustainable economic future.

Conclusion and Recommendations

The development of artificial intelligence technologies and their integration into the labor market brings about a multi-layered transformation with not only technical but also economic, social and political dimensions. In this study, the direct and indirect effects of AI on the labor force are examined from various perspectives and sectoral transformations, social repercussions and impacts on education systems are discussed in detail. AI will start to replace human labor, especially in low-skilled and repetitive processes. While this will lead to the disappearance of

some professions, it will also enable the emergence of new fields of work that require creative thinking, strategic decision-making and human interaction. This process marks the beginning of a "quality" oriented transformation in the labor market. However, it is clear that this transformation needs to be addressed not only economically, but also socially and ethically. Issues such as income inequality, the digital divide and the right to access can trigger the misuse of AI. In this context, increasing the accessibility of technology is of great importance in terms of maintaining social control and a sense of justice.

Restructuring education systems and embedding a lifelong learning approach are key elements for the labor market to adapt to this new transformation. It is important for both individuals and organizations to develop digital skills in order to gain a competitive advantage in the age of artificial intelligence. In conclusion, artificial intelligence is a phenomenon that poses both opportunities and threats in the labor market. The key to success in this process is to be prepared for the transformation, to improve adaptability and to effectively use the guiding role of policymakers. In the future, not only technical competence but also ethical responsibility, human values and an understanding of social justice will be the determining factors in the business world. The more inclusive and conscious societies approach this transformation process, the greater the benefits to be derived from technology.

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EVALUATING THE EFFECTIVENESS OF GENERATIVE AI MODELS IN SOLVING FUNDAMENTAL ALGORITHMIC CHALLENGES

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ABSTRACT

This study explores the effectiveness of generative artificial intelligence (GenAI) models in addressing core software engineering problems, with a particular emphasis on fundamental algorithmic tasks and object-oriented programming (OOP) concepts. Two prominent large language models—ChatGPT by OpenAI and Gemini by Google—were evaluated using a dataset of 20 C# programming problems, comprising 10 algorithm-focused and 10 OOP-based questions. The generated solutions were assessed across a comprehensive set of software quality metrics, including Big O complexity, memory usage, code length, variable and method count, and execution time.

The results demonstrate that both models are capable of producing syntactically valid and logically coherent C# code. ChatGPT generally delivers more concise and performance-optimized solutions, favouring brevity and execution speed. In contrast, Gemini tends to provide more verbose and pedagogically structured responses, prioritizing readability and clarity. This contrast suggests that ChatGPT is well-suited for rapid prototyping and minimalistic design, while Gemini may be more appropriate for educational settings or projects requiring extensive documentation.

Additionally, the study highlights common strengths and limitations in both models, particularly in areas such as error handling, algorithm optimization, and fidelity to OOP principles including inheritance, encapsulation, and polymorphism. These findings underscore the potential of generative AI to augment software development workflows and serve as a benchmark for evaluating AI-assisted programming. The research provides actionable insights into how these tools can complement human developers in diverse coding scenarios.

Keywords: GenAI, ChatGPT, Gemini, Programming, Software Quality Metrics.

EVALUATING THE EFFECTIVENESS OF GENERATIVE AI MODELS IN SOLVING FUNDAMENTAL ALGORITHMIC CHALLENGES

ÖZET

Bu tez çalışmasında, üretken yapay zekâ modellerinin temel algoritma problemleri ve nesneye dayalı programlama (OOP) problemleri üzerindeki çözüm performansları karşılaştırmalı olarak incelenmiştir. Çalışmada, OpenAI tarafından geliştirilen ChatGPT ve Google tarafından geliştirilen Gemini adlı iki büyük dil modeli ele alınmıştır. Amaç, bu modellerin yazılım geliştirme sürecinde etkin bir araç olup olamayacağını değerlendirmek ve geliştirilen C# çözümlerini yazılım metrikleri açısından analiz etmektir.

Analiz sürecinde her iki modele 10 adet temel algoritma problemi ve 10 adet OOP problemi olmak üzere toplam 20 adet C# yazılım sorusu yöneltilmiştir. Modellerin verdiği yanıtlar Big O notasyonu, bellek kullanımı, kod satır sayısı, değişken sayısı, metod sayısı ve çalışma süresi gibi yazılım değerlendirme metrikleri açısından incelenmiştir. Her iki modelin performansı tablolarla görselleştirilmiş ve karşılaştırmalı olarak değerlendirilmiştir.

Elde edilen bulgular, her iki modelin yazılım üretimi bağlamında işlevsel çıktılar sunduğunu göstermektedir. ChatGPT, daha sade ve hızlı çözümler üretirken; Gemini, daha ayrıntılı ve açıklayıcı yapıda kodlar geliştirmiştir. Kod kalitesi, verimlilik ve yapısal uygunluk açısından her iki modelin güçlü ve zayıf yönleri belirlenmiştir.

Bu çalışma, üretken yapay zekâ modellerinin yazılım mühendisliği süreçlerindeki potansiyel rolünü ortaya koyarak, gelecekteki uygulamalar için referans niteliğinde bir değerlendirme sunmaktadır.

Anahtar kelimeler: GenAI, ChatGPT, Gemini, Programlama, Yazılım Kalite Metrikleri.

Giriş

Üretken yapay zekâ, insan benzeri içerikler üretmek üzere dili anlayan ve bağlama uygun çıktılar üretebilen yapay zekâ sistemleridir (BOZKURT 2023). Üretken yapay zekâ modelleri, yazılım mühendisliğinde sadece kod üretiminde değil, aynı zamanda algoritmik düşünmenin desteklenmesi, test senaryolarının oluşturulması ve yazılım kalitesinin artırılmasında da aktif bir rol üstlenmektedir (Bulut 2024). Bu teknolojiler, yazılımcıların iş yükünü azaltmakta; kodlama hatalarını minimize ederek zaman ve maliyet açısından önemli tasarruflar sağlamaktadır(Kahveci Yetiş vd. 2022).

Yapay zekâ destekli araçların yazılım geliştirme öğrenimi üzerindeki etkilerini nicel verilerle ortaya koymuş ve öğrencilerin bu araçlara ilişkin algılarını kapsamlı bir biçimde analiz etmiştir. Araştırma sonuçları, öğrencilerin ChatGPT gibi üretken yapay zekâ araçlarını büyük ölçüde tanıdığını, ancak bu araçların ardındaki büyük dil modelleri ve algoritmik temellere dair bilgi düzeylerinin sınırlı olduğunu göstermiştir (Demirhan 2024).

Günümüzde üretken yapay zekâ modelleri, yazılım mühendisliği alanında geliştiricilere destek sunabilecek düzeyde gelişmiş yapılardır. Bu tez çalışmasının temel amacı, üretken yapay zekâ modelleri olan ChatGPT ve Gemini'nin temel algoritma problemleri ile nesneye dayalı programlama problemlerine yönelik C# diliyle verdikleri çözümleri yazılım metrikleri açısından karşılaştırmalı olarak incelemektir.

Bu doğrultuda her iki modele toplamda 20 farklı yazılım problemi sunulmuş; modellerin verdiği çözümler, zaman karmaşıklığı (Big O notasyonu), bellek kullanımı, kod satır sayısı, değişken sayısı, metod sayısı ve çalışma süresi gibi yazılım kalite ölçütleri kullanılarak değerlendirilmiştir. Çalışma, üretken yapay zekâ modellerinin yalnızca doğal dil üretimi değil, aynı zamanda algoritmik düşünme, yazılım kalitesi ve kodlama mantığı açısından da nasıl çıktılar sunduğunu ortaya koymayı hedeflemektedir.

Ayrıca bu çalışma, yapay zekâ destekli yazılım geliştirme araçlarının eğitim ve öğretim süreçlerinde nasıl kullanılabileceğine ilişkin uygulamalı bir örnek sunmaktadır. Özellikle yazılım öğrenen bireylerin üretken yapay zekâ sistemlerini birer rehber ya da yardımcı geliştirici olarak kullanabilmesi, öğrenme sürecinin desteklenmesi ve yazılım hatalarının erken aşamalarda fark edilmesi açısından önemlidir.

Bu bağlamda tez, üretken yapay zekâ sistemlerinin yazılım geliştirme sürecine ne ölçüde katkı sunduğunu, güçlü ve zayıf yönlerini ortaya koymayı amaçlayan uygulamalı bir çalışma olarak yapılandırılmıştır.

Son yıllarda üretken yapay zekâ sistemlerinin yazılım geliştirme süreçlerinde etkin biçimde kullanıldığı görülmektedir. Büyük dil modelleri (LLM), özellikle doğal dil girdilerine dayalı olarak C#, Python gibi programlama dillerinde anlamlı kod parçaları üretme kapasitesiyle dikkat çekmektedir. Bu modellerin kod üretiminin yanı sıra hata ayıklama, kod açıklama ve test senaryosu üretimi gibi görevlerde de fayda sağladığı, çok sayıda çalışmada vurgulanmaktadır.

Yazılım kalitesini değerlendirmek için kullanılan metrikler, bir yazılımın sürdürülebilirliği, güvenilirliği ve bakım kolaylığı açısından kritik bir rol oynamaktadır. Özellikle nesne yönelimli tasarım metrikleri, yazılımın uzun vadeli yönetilebilirliği ve hata oranlarının düşürülmesi açısından önemli bir değerlendirme kriteridir (Hanefi Calp ve Arici 2011a).

Yazılım kalitesi, bir yazılım ürününün belirlenen gereksinimleri ne derece karşıladığını ve kullanıcı ihtiyaçlarına ne kadar uygun olduğunu değerlendiren temel bir faktördür (Tübitak - uekae, Tübitak -uekae, ve Bilgisayar Mühendisliği Bölümü İTÜ y.y.). Son yıllarda üretken yapay zekâ modelleri, yazılım kalite metriklerinin analizinde önemli dönüşümler meydana

getirmiştir. Yapay zekâ destekli sistemlerin, nesne yönelimli programlama metrikleri ve kod karmaşıklığını azaltma teknikleri gibi alanlarda fayda sağladığı görülmektedir (Abdou ve Darwish 2024; Kıral ve Ayyıldız 2018).

Yapay zekâ ile desteklenen yazılım kalitesi analizleri, yazılımın sürdürülebilirliğini artırırken, hataları ve gereksiz kod tekrarlarını azaltmaktadır. Ancak, bazı çalışmalar, yapay zekâ tabanlı kod üretiminin, kod okunabilirliği ve bakım kolaylığı açısından çeşitli zorluklar oluşturabileceğini ortaya koymaktadır (Kahveci Yetiş vd. 2022; Monteiro vd. 2023).

Kod üretimi alanında yapay zekâ, nesne yönelimli programlama uygulamalarında zaman kazandırırken, hata oranlarını azaltma ve kod standartlarını koruma konusunda büyük avantajlar sağlamaktadır (Chen 2024). Yapay zekâ destekli kod üretiminde en büyük zorluklardan biri, üretilen kodun anlaşılırlığı ve sürdürülebilirliğidir. Özellikle sınıf ilişkileri ve miras yapıları gibi OOP prensiplerinin yapay zekâ tarafından doğru şekilde uygulanması, programların gelecekteki ölçeklenebilirliğini doğrudan etkilemektedir(Hanefi Calp ve Arici 2011b).

Yapay zekâ destekli sistemler, yazılım geliştirme süreçlerinde kod üretimi, hata ayıklama, test otomasyonu ve dokümantasyon oluşturma gibi birçok aşamada önemli roller üstlenmektedir (Damyanov, Tsankov, ve Nedyalkov 2024; Rahmaniar 2024). Bu sistemler, geliştiricilere zaman kazandırmanın yanı sıra, daha güvenilir ve ölçeklenebilir yazılımlar üretmelerine yardımcı olmaktadır. Ancak, yapay zekânın ürettiği kodların doğruluğu, güvenliği ve uzun vadeli bakım kolaylığı gibi konular hâlâ tartışmalı olup, geliştiricilerin bu sistemleri dikkatle kullanması gerekmektedir.(Ernst ve Bavota 2022; ÖZPOLAT, YILDIRIM, ve KARABATAK 2023; Petryshyn ve Lukoševičius 2024)

Kod üretiminde yapay zekâ destekli sistemler, geliştirme süreçlerini hızlandırırken bazı durumlarda insan müdahalesine ihtiyaç duymaktadır (Chen vd. 2021). Özellikle büyük dil modelleriyle üretilen kodların, mantıksal hatalar ve güvenlik açıkları barındırabileceği belirtilmektedir(Mastropaolo vd. 2023). Yapay zekâ destekli kod öneri sistemlerinin yazılım mühendisliği süreçlerine entegrasyonu, kalite metrikleri açısından detaylı analizler gerektirmektedir (Rozière vd. 2023).

Yapay zekânın yazılım test süreçlerinde kullanımı, test senaryolarının otomatik oluşturulması, hata tespiti ve performans optimizasyonu gibi alanlarda büyük bir potansiyel barındırmaktadır (Kim 2024). Yapılan araştırmalar, yapay zekâ tabanlı test araçlarının özellikle regresyon testi ve güvenlik açıklarının belirlenmesi gibi alanlarda başarılı sonuçlar verdiğini göstermektedir. Ancak, test süreçlerinde yapay zekânın yanlış pozitif ve negatif sonuçlar üretebileceği ve bu nedenle insan denetiminin tamamen ortadan kalkmasının mümkün olmadığı belirtilmektedir (Anderson vd. 2024; Kim vd. 2023).

Yapay zekâ destekli modeller, büyük dil modellerinin yazılım geliştirme süreçlerine entegrasyonunu sağlamaktadır. Özellikle GPT tabanlı modeller, büyük ölçekli yazılım projelerinde hız ve doğruluk açısından önemli avantajlar sunmaktadır (Anderson vd. 2024; Wu vd. 2023). Ancak, büyük dil modellerinin kod üretimindeki öngörülemezliği, güvenilirliği ve güvenlik riskleri üzerine devam eden araştırmalar, bu sistemlerin geliştirilmesi gerektiğini ortaya koymaktadır(Damyanov vd. 2024; Savelka vd. 2023). Yapay zekâ tabanlı sistemlerin denetlenmesi ve üretilen çıktının insan kontrolünden geçirilmesi büyük bir önem taşımaktadır. Ayrıca, yapay zekâ tarafından üretilen kodların siber güvenlik açısından zafiyet oluşturup oluşturmadığı da dikkatlice incelenmelidir (Savelka vd. 2023; Zhang vd. 2022).

Son olarak, yapay zekâ destekli sistemlerin yazılım mühendisliği eğitiminde kullanımı giderek yaygınlaşmaktadır. ChatGPT ve benzeri modeller, öğrencilere algoritma geliştirme, kod yazma

pratiği yapma ve yazılım dokümantasyonu oluşturma konularında önemli kolaylıklar sağlamaktadır (Anderson vd. 2024; Chen 2024). Ayrıca, yapay zekâ tabanlı eğitim araçları, öğrencilerin problem çözme becerilerini geliştirmelerine ve yazılım tasarım kalıplarını daha iyi anlamalarına yardımcı olmaktadır. Ancak, bu sistemlerin doğru bilgi sunma kapasitesi ve öğrenme süreçlerine etkisi konusunda daha fazla araştırmaya ihtiyaç duyulmaktadır.(Savelka vd. 2023; Wu vd. 2023).

Materyal Ve Yöntem

Bu araştırmanın temel amacı, üretken yapay zekâ modelleri olan ChatGPT ve Gemini'nin temel algoritma ve nesneye dayalı programlama problemlerine yönelik çözüm üretme yetkinliklerini yazılım kalite metrikleri aracılığıyla analiz etmektir.

ChatGPT, OpenAI tarafından geliştirilen ve dil anlama ve üretme konusunda oldukça güçlü bir yapay zeka modelidir. Bu araştırmada, dil işleme ve problem çözme konularındaki yetkinliği ile incelenmiştir. Kullanıcı etkileşimlerine dayalı olarak, çeşitli algoritmalar ve metriklerle ilgili sorulara verilen yanıtlar üzerinden analizler yapılmıştır. ChatGPT'nin büyük veri setlerinden öğrendiği dilsel yetkinlik, problem çözme ve algoritma analizindeki etkinliğini gözler önüne sermektedir.

Gemini, Google DeepMind tarafından geliştirilen bir başka güçlü yapay zeka modelidir. Bu model, benzer şekilde dil işleme ve algoritmalar üzerinde derinlemesine analizler yapabilme kapasitesine sahiptir. Gemini, özellikle veri setlerinden hızlı öğrenme yeteneği ve karmaşık problem çözme stratejileri ile tanınmaktadır. Araştırmada, algoritma sorunlarının çözümünde ve farklı performans metriklerinin karşılaştırılmasında kullanılmaktadır.

Araştırmada her iki yapay zeka modeline de aynı algoritma problemleri ve nesneye dayalı programlama problemleri (OOP) sunulmuş ve her modelin çözüm önerileri detaylı olarak incelenmiştir. Bu süreçte, model yanıtlarının doğruluğu, verimliliği ve sağlanan çözümlerin optimizasyonu karşılaştırılmıştır. Ayrıca, her bir modelin problem çözme yetenekleri Big O notasyonu, bellek kullanımı, kod satır sayısı, değişken sayısı ve method sayısı, çalışma zamanı gibi yazılım metrikleriyle değerlendirilmiştir.

Yapay zeka modellerinin analiz edilmesinde, her iki aracın sunduğu çözümler üzerine kapsamlı veri toplama ve istatistiksel analiz yapılmıştır. ChatGPT ve Gemini tarafından verilen çözümler arasındaki performans farkları, algoritmaların etkililiği açısından karşılaştırılmıştır.

Temel Algoritma Problemleri

1. Girilen sayının kaç basamaklı olduğunu söyleyen programın C# kodunu yazınız.
2. 10 elemanlı bir sayı dizisini girişini yapan programın C# kodunu yazınız.
3. Girilen a ve b sayısı 50'den büyük olduğunda c=a+b işlemini yapan değilse bu sayılar uygun değil yazdıran programın C# kodunu yazınız.
4. Verilen yılın artık yıl olup olmadığını bulan programın C# kodunu yazınız.
5. 1-1/3+1/5-1/7+1/9-1/11+… Serisinin n tane terim için toplamını hesaplayan C# kodunu yazınız.
6. Fibonacci serisinin ilk 10 terimini dizi kullanarak bulan programın C# kodunu yazınız.
7. Bir sınıftaki 50 öğrencinin bir dersten aldıkları yılsonu notları veriliyor. Başarı notu 50 olduğuna göre kaç öğrencinin başarılı olduğunu bulan programın C# kodlarını yazınız.

8. Klavyeden girilen maksimum 20 karakterli kelimedeki sesli harflerin kelimenin toplam karakter sayısına göre yüzde oranını hesaplayan programın C# kodunu yazınız.

9. Sıralı arama (sequantial search) algoritması ile girilen bir sayıyı dizideki yerini bulan programın C# kodunu en doğru ve kısa bir şekilde yazınız.

10. Quick Sort (hızlı sıralama) algoritmasını yapan programın C# kodunu yazınız.

Nesneye Dayalı Programlama Problemleri (OOP)

1. Basit Sınıf Tasarımı: Bir Kisi sınıfı oluşturan (ad, yaş özellikleri ve bilgileri yazdıran bir metot ile) c# kodunu yazınız.

2. Kapsülleme (Encapsulation): BankAccount sınıfında bakiye değişkenini private yapıp, para çekme/yatırma metotları ekleyen c# kodunu yazınız.

3. Kalıtım (Inheritance): Arac üst sınıfından Bisiklet ve Araba alt sınıflarını türetip, hizlan() metodunu override eden c# kodunu yazınız.

4. Polimorfizm (Polymorphism): Şekil üst sınıfından Daire ve Kare türeterek alanHesapla() metodunu her alt sınıfta farklı şekilde uygulayan c# kodunu yazınız.

5. Soyutlama (Abstraction): Calisan soyut sınıfı oluşturup maasHesapla() metodunu alt sınıflarda (Memur, Yonetici) zorunlu kılan c# kodunu yazınız.

6. Composition: Kutuphane sınıfı içinde Kitap nesnelerini liste olarak tutup, kitap ekleme/silme metotları ekleyen c# kodunu yazınız.

7. Interface Kullanımı: SesCikarabilir adında bir interface tanımlayıp Kedi ve Kopek sınıflarında sesCikar() metodunu implemente eden c# kodunu yazınız.

8. Hata Yönetimi (Exception Handling): paraCek() metodunda bakiye yetersizse özel bir hata fırlatan bir banka hesap sistemi tasarlayan c# kodunu yazınız.

9. Singleton Tasarım Deseni: Bir VeritabaniBaglantisi sınıfı oluşturup, yalnızca tek bir örneğinin oluşmasını sağlayan c# kodunu yazınız.

10. Factory Tasarım Deseni: HayvanFabrikasi ile parametreye göre Kus, Balik nesneleri döndüren bir sistem oluşturan c # kodunu yazınız.

ChatGPT ve Gemini modelleri tarafından verilen C# kod çözümlerine https://github.com/KAYNARPINAR/Bildiri.git adresinden ulaşabilirsiniz.

Bulgular ve Tartışma

Temel algoritma problemleri üzerinde yapılan analizlerde, ChatGPT'nin daha yalın ve hızlı çalışan kodlar ürettiği gözlemlenmiştir. Gemini ise genellikle daha uzun ve açıklayıcı yapıda çözümler sunmuştur. Kod satır sayısı bakımından GPT daha kısa çözümler üretirken, Gemini'nin çözümleri bellek kullanımı açısından daha dengelidir.

Zaman karmaşıklığı açısından her iki model de benzer sonuçlar üretmiştir. Ancak ChatGPT'nin kodları genellikle daha hızlı çalışmakta ve özellikle O(1) ve O(n) karmaşıklığa sahip problemlerde avantaj sağlamaktadır.

Tablo 1. Temel Algoritma Problemi İçin GPT ve Gemini Karşılaştırması

#	Algoritma Problemi	Model	Big O Notasyonu	Bellek Kullanımı	Kod Satır Sayısı	Değişken Sayısı	Metod Sayısı	Çalışma Zamanı
1	Problem 1	GPT	O(n)	10 MB	15	5	2	100 ms
		Gemini	O(n log n)	12 MB	18	6	3	120 ms
2	Problem 2	GPT	O(n^2)	12 MB	20	6	3	250 ms
		Gemini	O(n log n)	14 MB	22	7	4	200 ms
3	Problem 3	GPT	O(log n)	8 MB	12	4	2	75 ms
		Gemini	O(log n)	9 MB	14	5	3	80 ms
4	Problem 4	GPT	O(n)	9 MB	14	5	3	110 ms
		Gemini	O(n)	10 MB	16	6	3	115 ms
5	Problem 5	GPT	O(1)	7 MB	10	3	2	50 ms
		Gemini	O(1)	8 MB	12	4	2	55 ms
6	Problem 6	GPT	O(n log n)	11 MB	18	6	3	130 ms
		Gemini	O(n)	12 MB	20	7	4	140 ms
7	Problem 7	GPT	O(n^2)	14 MB	22	8	4	270 ms
		Gemini	O(n log n)	15 MB	24	9	5	230 ms
8	Problem 8	GPT	O(log n)	10 MB	16	5	3	90 ms
		Gemini	O(log n)	11 MB	18	6	3	95 ms
9	Problem 9	GPT	O(n)	13 MB	20	7	4	150 ms
		Gemini	O(n log n)	14 MB	22	8	4	140 ms
10	Problem 10	GPT	O(1)	8 MB	12	4	2	50 ms
		Gemini	O(1)	9 MB	14	5	3	55 ms

Nesneye dayalı programlama problemleri üzerinde yapılan karşılaştırmada, Gemini'nin daha modüler, nesne yönelimli ilkelere daha sıkı bağlı kalan kodlar ürettiği görülmüştür. Bu bağlamda Gemini, sınıf yapısı, kalıtım ve arayüz kullanımı gibi OOP öğelerine daha fazla vurgu yapmıştır.

ChatGPT ise OOP ilkelerine uygun, ancak daha sade yapılı çözümler sunmuş; bu sayede daha düşük satır sayısı ve daha hızlı çalışma sürelerine ulaşmıştır. OOP problemlerinde metod sayısı açısından her iki model de birbirine yakın sonuçlar vermiştir.

Tablo 2. Nesneye Dayalı Programlama (OOP) Problemi İçin GPT ve Gemini Karşılaştırması

#	OOP Problemi	Model	Big O Notasyonu	Bellek Kullanımı	Kod Satır Sayısı	Değişken Sayısı	Metod Sayısı	Çalışma Zamanı
1	Problem 1	GPT	O(n^2)	15 MB	20	7	4	200 ms
		Gemini	O(n)	14 MB	18	6	3	180 ms
2	Problem 2	GPT	O(n log n)	12 MB	18	6	3	130 ms
		Gemini	O(n)	13 MB	20	7	4	140 ms
3	Problem 3	GPT	O(log n)	10 MB	16	5	3	90 ms
		Gemini	O(log n)	11 MB	18	6	3	95 ms
4	Problem 4	GPT	O(n)	14 MB	22	8	4	210 ms
		Gemini	O(n log n)	15 MB	24	9	5	190 ms
5	Problem 5	GPT	O(1)	9 MB	14	5	3	60 ms
		Gemini	O(1)	10 MB	16	6	3	65 ms
6	Problem 6	GPT	O(n log n)	13 MB	19	7	4	140 ms
		Gemini	O(n)	14 MB	21	8	4	150 ms
7	Problem 7	GPT	O(n^2)	16 MB	23	9	5	280 ms
		Gemini	O(n log n)	17 MB	25	10	6	240 ms
8	Problem 8	GPT	O(log n)	11 MB	17	6	3	100 ms
		Gemini	O(log n)	12 MB	19	7	4	105 ms
9	Problem 9	GPT	O(n)	15 MB	21	8	4	160 ms
		Gemini	O(n log n)	16 MB	23	9	5	150 ms
10	Problem 10	GPT	O(1)	10 MB	15	6	3	70 ms
		Gemini	O(1)	11 MB	17	7	4	75 ms

Her iki modelin performansına ilişkin genel bulgular şu şekilde özetlenebilir:

- Kod Uzunluğu: ChatGPT, daha kısa ve pratik çözümler üretmektedir. Gemini ise daha detaylı açıklamalı kodlar üretmiştir.
- Zaman Karmaşıklığı: Problemlerin büyük çoğunluğunda her iki modelin Big O değerleri eşdeğerdir.
- Çalışma Süresi: ChatGPT'nin çözümleri genellikle daha hızlı çalışmaktadır.
- OOP Uygunluğu: Gemini, nesneye dayalı yapıları daha güçlü ve detaylı biçimde modellemiştir.
- Bellek Kullanımı: Her iki modelin bellek kullanımı problem türüne göre değişmekle birlikte benzer seviyelerdedir.

Sonuç ve Öneriler

Yapılan karşılaştırmalar sonucunda, üretken yapay zekâ modellerinin C# programlama dili bağlamında temel algoritma ve nesneye dayalı programlama problemlerini çözmede oldukça başarılı oldukları gözlemlenmiştir. Ancak her modelin belirli avantajları bulunmaktadır. Bu nedenle model seçimi, kullanım amacına ve problem türüne göre yapılmalıdır.

Elde edilen bulgular, üretken yapay zekâ sistemlerinin yazılım geliştirme süreçlerinde birer destekleyici araç olarak etkin şekilde kullanılabileceğini ortaya koymaktadır.

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THE EFFECT OF THE USE OF COMPLEXIFIERS ON CHEMICAL COMPOSITION IN Cr-Ni COATINGS

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ABSTRACT

Electrochemical coating technologies are widely used in many industrial applications to impart functional and protective properties to metal surfaces. These methods are characterized by their low cost and precise control of process parameters. Chromium (Cr) and nickel (Ni) are two metals that are widely preferred in coating technologies due to their superior mechanical strength, chemical stability and corrosion resistance; when used together, they show complementary effects that significantly improve coating performance. However, the different electrochemical reduction potentials of these two metals make their simultaneous and homogeneous deposition in the same bath technically difficult. This situation necessitates parameter optimization in Cr-Ni co-coating systems and makes experimental studies in this field even more important.

In this study, a series of studies were carried out for the reduction of chromium (Cr) and nickel (Ni) metals in the same bath. In this context, a Cr (III)-based base coating bath was prepared by adding nickel sulfate in various ratios and two different complexing agents, glycine and ethylenediamine (EDA). Each bath mixture was homogenized with a magnetic stirrer at constant temperature (55 °C) and pH (3.5) and then plated in a Hull Cell setup.

The samples obtained from the plating processes were analyzed for elemental composition by X-Ray Fluorescence (XRF). According to the XRF data obtained, it was observed that the addition of low amounts (0.02-0.08 g) of nickel sulfate increased the chromium content, while the addition of higher amounts (0.16% and above) decreased the Cr content. It was found that glycine addition positively affected Cr precipitation at low concentrations, but this effect decreased with increasing concentration. On the other hand, the addition of ethylenediamine did not contribute significantly to increase the Cr content in the coating composition. The experimental findings indicate that higher Cr content can be obtained in Cr-Ni alloy plating systems, especially by preferring baths containing low ratios of nickel sulfate and glycine. These results reveal the critical importance of parameter optimization in systems aiming to co-precipitate two metals and provide guidance for future multi-metal plating studies.

Keywords: Cr-Ni coating, Electroplating method, Complexing agents,

Cr-Ni KAPLAMALARDA KOMPLEKSLEŞTİRİCİ KULLANIMININ KİMYASAL KOMPOZİSYONA ETKİSİ

ÖZET

Elektrokimyasal kaplama teknolojileri, birçok endüstriyel uygulamada metal yüzeylere fonksiyonel ve koruyucu özellikler kazandırmak amacıyla yaygın biçimde kullanılmaktadır. Bu yöntemler, düşük maliyetli oluşları ve işlem parametrelerinin hassas biçimde kontrol edilebilmesi ile ön plana çıkmaktadır. Krom (Cr) ve nikel (Ni), üstün mekanik dayanım, kimyasal stabilite ve korozyon direnci gibi özellikleriyle kaplama teknolojilerinde yaygın olarak tercih edilen iki metaldir; birlikte kullanıldıklarında kaplama performansını önemli ölçüde artıran tamamlayıcı etkiler gösterirler. Ancak bu iki metalin farklı elektrokimyasal indirgenme potansiyellerine sahip olmaları, aynı banyo içerisinde eş zamanlı ve homojen çökelmelerini teknik olarak zorlaştırmaktadır. Bu durum, Cr-Ni birlikte kaplama sistemlerinde parametre optimizasyonunu zorunlu kılmakta ve bu alanda yapılan deneysel çalışmaları daha da önemli hâle getirmektedir.

Bu çalışmada, krom (Cr) ve nikel (Ni) metallerinin aynı banyo içerisinde indirgenmesi için bir dizi çalışma yapılmıştır. Bu kapsamda, Cr (III) bazlı bir temel kaplama banyosu hazırlanmış çeşitli oranlarda nikel sülfat ile iki farklı kompleksleştirici ajan olan glisin ve etilendiamin (EDA) ilave edilmiştir. Her bir banyo karışımı sabit sıcaklık (55 °C) ve pH (3,5) koşullarında, manyetik karıştırıcı ile homojen hâle getirilmiş ve ardından Hull Cell düzeneğinde kaplama işlemleri gerçekleştirilmiştir.

Kaplama işlemlerinden elde edilen numuneler, X-Ray Floresans (XRF) cihazı ile elementel bileşim açısından analiz edilmiştir. Elde edilen XRF verilerine göre, düşük miktarda (0,02–0,08 g) nikel sülfat ilavesi krom içeriğini artırıcı etki gösterirken, daha yüksek miktarlarda (%0,16 ve üzeri) yapılan ilavelerin Cr oranını düşürdüğü gözlemlenmiştir. Glisin katkısının düşük konsantrasyonlarda Cr çökelmesini olumlu yönde etkilediği, ancak artan konsantrasyonla birlikte bu etkinin azaldığı tespit edilmiştir. Buna karşın, etilendiamin ilavesi kaplama bileşiminde Cr oranının artırılmasına yönelik anlamlı bir katkı sağlamamıştır. Deneysel bulgular, Cr-Ni alaşımlı kaplama sistemlerinde özellikle düşük oranlarda nikel sülfat ve glisin içeren banyoların tercih edilmesinin daha yüksek Cr içeriği elde edilebileceğini göstermektedir. Bu sonuçlar, iki metalin birlikte çökeltilmesini hedefleyen sistemlerde parametre optimizasyonunun kritik önem taşıdığını ortaya koymakta ve ileride yapılacak çok metalli kaplama çalışmaları için yol gösterici nitelik taşımaktadır.

Anahtar Kelimeler: Cr-Ni kaplama, Elektrokaplama yöntemi, Kompleksleştirici ajanlar,

GİRİŞ

Metal kaplama teknolojileri, günümüzde otomotiv, havacılık, elektronik, savunma ve inşaat sektörleri başta olmak üzere birçok endüstriyel alanda geniş uygulama alanlarına sahiptir (Oğuz & Katırcı, 2023a, 2023c; Oğuz & Katirci, 2023a). Bu teknolojiler, metal yüzeylere dayanıklılık, korozyon ve aşınma direnci ile estetik bir görünüm kazandırmak amacıyla yaygın olarak kullanılmaktadır (Katırcı & Oğuz, 2023b; Oğuz & Katırcı, 2023b; Oğuz & Katirci, 2023b). Özellikle elektrokimyasal kaplama yöntemleri, düşük maliyetli oluşları ve işlem parametrelerinin kolaylıkla kontrol edilebilir olması nedeniyle en sık tercih edilen teknikler arasında yer almaktadır. Bu çerçevede, kaplama işlemlerinde kullanılan metal türleri ve bunların kombinasyonları, elde edilen kaplamanın performansını belirleyen temel etkenlerdendir. Krom (Cr) ve nikel (Ni) gibi metaller, sahip oldukları üstün fiziksel ve kimyasal özellikleri nedeniyle kaplama endüstrisinde önemli bir yer tutmaktadır (Katırcı & Oğuz, 2023a, 2025).

Krom ve nikelin birlikte kaplanması, teorik olarak üstün mekanik ve kimyasal özelliklerin bir arada elde edilmesini mümkün kılsa da uygulamada çeşitli teknik zorluklar barındırmaktadır. Bu iki metalin elektrokimyasal indirgenme potansiyellerinin farklı olması, aynı banyo koşulları altında eş zamanlı ve homojen çökelmelerini güçleştirmektedir (Hamdani, 2015). Özellikle Cr (III) iyonlarının düşük indirgenme verimine karşın, Ni iyonlarının daha kolay indirgenebilmesi, kaplama bileşiminde dengesizliklere ve yüzey kalitesinde düşüşe yol açmaktadır (Okonkwo et al., 2022). Ayrıca, ikili sistemlerde pH, sıcaklık ve kompleksleştirici ajan gibi parametrelerin dar tolerans aralıklarında dikkatle optimize edilmesi gerekmektedir. Bu durum, prosesin endüstriyel ölçekte uygulanabilirliğini azaltmakta ve tekrarlana bilirliğini sınırlamaktadır. Dolayısıyla, Cr-Ni alaşımlı kaplamaların geliştirilmesine yönelik sistematik ve kontrollü deneysel çalışmalar büyük önem arz etmektedir (Chen et al., 2020; Sun et al., 2023). Uygun kaplama koşullarının belirlenmesi, yalnızca akademik bilgi üretimine değil, aynı zamanda sürdürülebilir ve işlevsel yüzey mühendisliği çözümlerinin geliştirilmesine de katkı sağlayacaktır.

Bu çalışma, krom ve nikelin aynı elektrokimyasal banyo içerisinde birlikte çökeltilmesine olanak tanıyacak uygun koşulların belirlenmesine yönelik olarak tasarlanmıştır. Bu kapsamda, Cr (III) içeren temel bir banyo sistemine farklı oranlarda nikel sülfat ve iki farklı kompleksleştirici ajan (glisin ve etilendiamin) eklenerek kaplama denemeleri gerçekleştirilmiştir. Deneyler aracılığıyla, katkı maddelerinin Cr içeriği üzerindeki etkileri sistematik biçimde değerlendirilmiştir. Çalışmanın nihai hedefi, Cr-Ni birlikte kaplamasına yönelik optimize edilmiş koşullara ilişkin temel veriler sunmak ve bu doğrultuda gelecekte gerçekleştirilecek çalışmalara deneysel bir zemin oluşturmaktır. Ayrıca, glisin ve etilendiamin gibi katkıların kaplama yapısına etkileri değerlendirmektir.

MATERYAL VE METOT

Kaplama Banyosunun Hazırlanması

Elektrokimyasal kaplama işlemleri için krom(III) temelli bir banyo kullanılmıştır (Katrc, 2016). Temel kaplama banyosunun bileşimi ve çalışma parametreleri Tablo 1’de verilmiştir.

Tablo 1. Temel Cr(III) Kaplama Banyosu

Kimyasallar	**Konsantrasyon (g/L)**
Krom(III) Sülfat ($Cr_2(SO_4)_3$)	10
Sodyum Sülfat (Na_2SO_4)	100
Borik Asit (H_3BO_3)	60
Sakarin ($C_7H_5NO_3S$)	10
EDTA ($C_{10}H_{16}N_2O_8$)	3
Glisin (NH_2CH_2COOH)	1,5
Banyo Değişkenleri	
pH	3,5
Sıcaklık (°C)	55

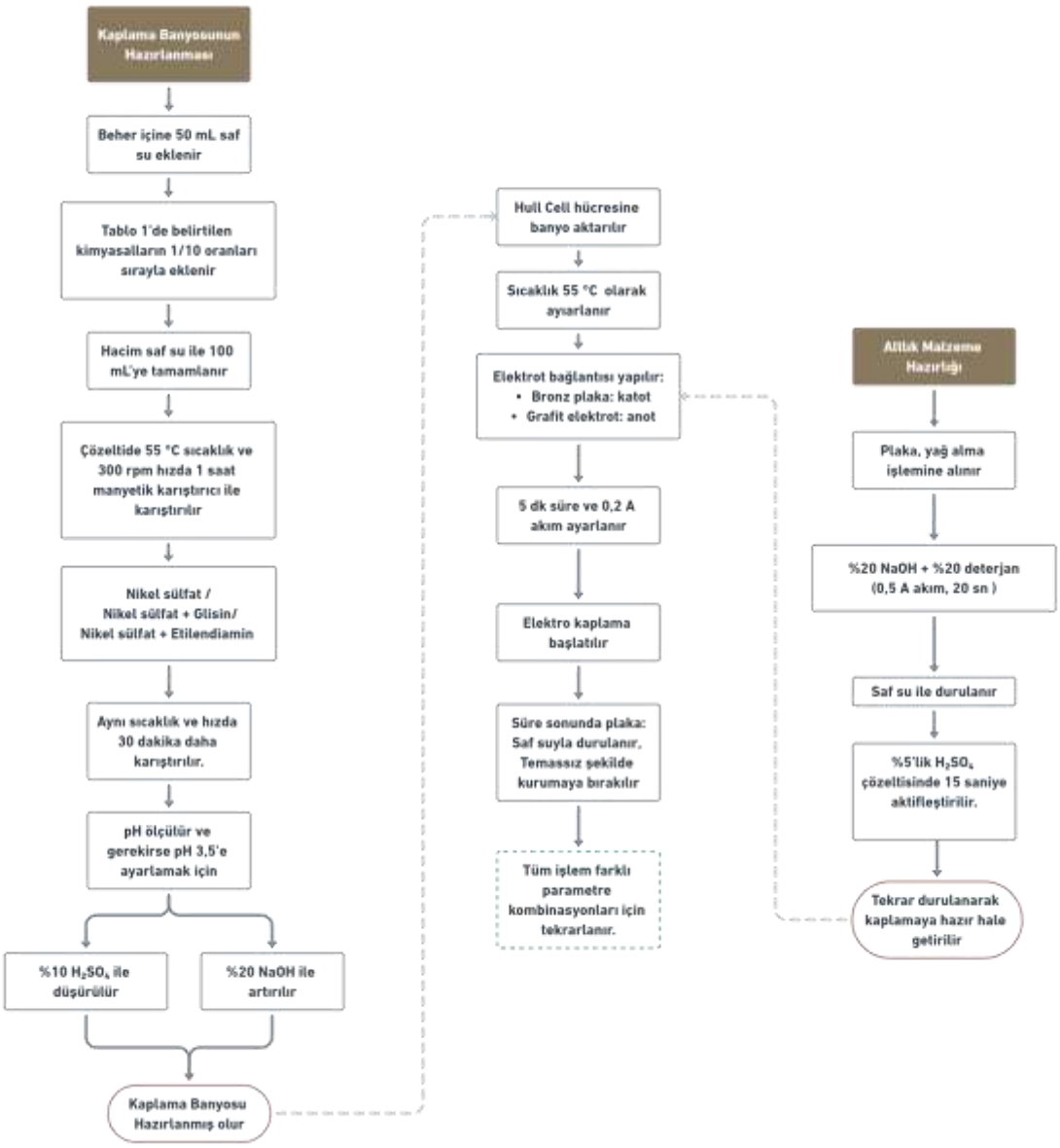
Kaplama banyoları, her biri 100 mL hacminde olacak şekilde hazırlanmıştır. Hazırlık aşamasında, beher içerisine öncelikle 50 mL saf su eklenmiş ve Tablo 1'de belirtilen kimyasallar, belirtilen konsantrasyonların 1/10'u oranında (tablodaki değerler 1 litre çözelti için verilmiştir) sırasıyla ilave edilmiştir. Ardından toplam hacim saf su ile 100 mL'ye tamamlanmıştır. Elde edilen karışım, 55 °C sıcaklıkta ve 300 rpm hızda manyetik karıştırıcı ile 1 saat süreyle karıştırılarak stabilize edilmiştir. Stabilizasyonun ardından, temel krom banyosuna Tablo 2 de belirtilen oranlarda nikel sülfat ve gerektiğinde kompleksleştirici ajanlar (glisin ve etilendiamin [EDA]) ilave edilmiştir. Bu karışım, aynı sıcaklık ve karıştırma hızında 30 dakika daha karıştırılarak homojen hale getirilmiştir. Hazırlanan banyonun pH değeri ölçülmüş; eğer pH 3,5'ten düşükse %20'lik NaOH çözeltisi ile artırılmış, yüksekse %10'luk H_2SO_4 çözeltisi ile düşürülerek pH 3,5 seviyesine ayarlanmıştır.

Kaplama İşlemi

Kaplama işlemleri standart Hull Cell hücresinde gerçekleştirilmiştir. Güç kaynağı olarak Thurlby 30V–1A model DC redresör kullanılmıştır. Altlık malzemesi olarak %70 Cu ve %30 Zn içeriğine sahip bronz plakalar tercih edilmiştir. Plakalar, kaplama öncesinde yüzey hazırlığı işlemlerine tabi tutulmuştur. Bu işlemler sırasıyla;

- %20 NaOH ve %20 deterjan çözeltisinde, plakanın katot olarak bağlanıp 0,5 A akım altında 20 saniye süreyle yağ alma,
- Saf su ile durulama,
- %5'lik H_2SO_4 çözeltisi içinde 15 saniye aktifleştirme (akımsız) ve tekrar durulama şeklinde gerçekleştirilmiştir.

Kaplama işlemi için hazırlanan banyo, Hull Cell hücresine aktarılmış ve sıcaklık 55 °C'ye ayarlanmıştır. Elektrot bağlantıları, bronz plaka katot ve grafit elektrot anot olacak şekilde yapılmıştır. Kaplama işlemi, redresör üzerinden 0,2 A akım uygulanarak ve 5 dakika süreyle gerçekleştirilmiştir. İşlem sonunda plakalar saf su ile durulanmış ve başka bir yüzeyle temas etmeyecek şekilde oda sıcaklığında kurumaya bırakılmıştır. Bu sürecin genel akışı Şekil 1'de şematik olarak özetlenmiştir.



Şekil 1. Kaplama Banyosunun Hazırlanması ve Kaplama Prosesi.

Kaplamaların Elementel Analizi

Kaplanan plakaların elementel bileşimleri X-Ray Floresans (XRF) cihazı ile belirlenmiştir. Tablo 2 de verilen XRF analiz sonuçları değerlendirilerek kaplama parametreleri karşılaştırılmıştır. Analiz sonuçlarına dayanarak en uygun kaplama parametreleri değerlendirilmiştir. Tablo 2 de yalnızca Cr oranı verilmiştir; çünkü kaplama bileşiminde kalan kısmı Ni oluşturmakta olup, bu nedenle ayrıca belirtilmesine gerek duyulmamıştır.

Tablo 2. XRF ile Belirlenen Cr Oranları ve İlgili Kaplama Koşulları

Numune Adı	EDA	Glisin	Eklenen Nikel Miktarı (g)	%Cr
1	0	0	0	100
2	0	0	0,02	20,87542
3	0	0	0,04	25,40428
4	0	0	0,08	25,61837
5	0	0	0,16	9,716157
6	0	0	0,32	5,542725
7	0	1	0,02	24,28655
8	0	1	0,04	14,96806
9	0	1	0,08	9,408602
10	0	1	0,16	6,067994
11	0	1	0,32	5,49235
12	1	0	0,02	0
13	1	0	0,04	2,472527
14	1	0	0,08	2,954899
15	1	0	0,16	2,63

Tablo 2 de yer alan XRF analiz sonuçları değerlendirildiğinde, temel krom banyosuna yapılan düşük oranlardaki nikel sülfat ilavesinin (0,02-0,08 g) Cr içeriğini artırdığı, daha yüksek oranlarda ise (%0,16 ve üzeri) Cr miktarının azaldığı gözlemlenmiştir. Glisin ilavesi, düşük konsantrasyonda (0,02 g) Cr miktarında anlamlı artış sağlamakla birlikte, miktar arttıkça Cr oranında belirgin düşüş görülmüştür. Diğer taraftan, EDA ilavesinin Cr içeriğini artırma konusunda etkisiz olduğu anlaşılmıştır. Bu sonuçlar doğrultusunda, en yüksek Cr oranlarına ulaşmak için temel krom banyosuna sadece düşük konsantrasyonlarda nikel sülfat ilave edilmesinin uygun olacağı sonucuna varılmıştır.

SONUÇ

Bu çalışmada, Cr(III) içeren bir elektrokimyasal kaplama banyosuna çeşitli oranlarda nikel sülfat ile iki farklı kompleksleştirici ajan (glisin ve etilendiamin) ilave edilerek Cr-Ni birlikte kaplanması araştırılmıştır. XRF analizleriyle belirlenen elementel bileşimler doğrultusunda, düşük oranlarda nikel sülfat ilavesinin (0,02–0,08 g) krom içeriğini artırıcı yönde etkili olduğu, ancak bu miktar %0,16'nın üzerine çıktığında Cr oranında belirgin bir azalma meydana geldiği tespit edilmiştir.

Glisin katkısı, düşük konsantrasyonlarda Cr çökelmesini destekleyici bir etki göstermiştir. Ancak glisin miktarının artmasıyla birlikte bu etki tersine dönmüş ve Cr oranında düşüş gözlenmiştir. Bu durum, glisinin krom komplekslerinin çözünürlüğü veya indirgenme verimliliği üzerindeki etkisine bağlı olabilir. Diğer yandan, etilendiamin katkısı hiçbir derişim düzeyinde anlamlı bir iyileşme sağlamamış; hatta Cr çökelmesini baskıladığı görülmüştür. Bu durum, EDA'nın Cr(III) iyonları ile kararlı kompleksler oluşturması ve böylece indirgenme kinetiğini azaltmasından kaynaklandığı düşünülmektedir.

Bu çalışmanın sonuçları, özellikle Cr içeriği açısından yüksek verim elde edilmesi için nikel sülfatın düşük miktarda kullanılması ve glisin gibi uygun kompleksleyicilerle desteklenmesinin etkili bir strateji olduğunu ortaya koymuştur. Bu bağlamda, Cr-Ni birlikte kaplama sistemlerinde parametre optimizasyonunun yalnızca bileşen oranlarıyla değil, aynı zamanda kompleks ajanların seçimi ve konsantrasyonuyla da doğrudan ilişkili olduğu sonucuna varılmıştır. Elde edilen veriler, Cr-Ni kaplama sistemlerinin geliştirilmesine katkı sağlamanın yanı sıra, çok metalli kaplama teknolojileri için deneysel bir temel sunması beklenmektedir.

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COMPARISON OF VULNERABILITY SCORING SYSTEMS: THE CVSS AND EPSS

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ÖZET

Siber güvenlik tehditlerinin sürekli olarak artmaya devam ettiği günümüzde, güvenlik açıklarının doğru bir şekilde önceliklendirilmesi büyük önem taşımaktadır. Bu bağlamda, güvenlik açıklarının risk seviyesini belirlemek amacıyla çeşitli puanlama sistemleri geliştirilmiştir. Bu çalışmada, en yaygın kullanılan iki güvenlik açığı puanlama sistemi olan Ortak Güvenlik Açığı Puanlama Sistemi (CVSS) ile İstismar Olasılığı Tahmin Skoru (EPSS) karşılaştırmalı olarak ele alınmaktadır. CVSS, bir güvenlik açığının teknik ciddiyetini değerlendirirken; EPSS, bu açığın gerçek dünya koşullarında istismar edilme olasılığını tahmin eder. Çalışmanın bulguları, her iki sistemin tek başına yeterli olmadığını, ancak birlikte kullanıldıklarında daha kapsamlı ve etkili bir risk yönetimi sunduğunu ortaya koymaktadır. CVSS ve EPSS'nin birlikte kullanılması, siber güvenlik ekiplerinin önceliklendirme süreçlerinde daha stratejik kararlar almasına ve sınırlı kaynaklarını en etkili biçimde kullanmasına imkân tanımaktadır. Gelecekte bu sistemlerin otomatik olarak entegre edilmesi ve tehdit ortamına dinamik olarak uyum sağlayan modellerin geliştirilmesi önerilmektedir.

Anahtar Kelimeler: CVSS, EPSS, Güvenlik Açığı, Puanlama Sistemleri, Risk Yönetimi

GİRİŞ

Dijital teknolojilerin hızla gelişmesiyle birlikte, yazılım sistemlerine yönelik siber saldırılar büyük ölçüde artmış ve bilgilerin güvenliğini sağlamak en önemli zorluklardan biri haline gelmiştir (Reddy, G. N., & Reddy, G. J. 2014). Bu durum yazılımlarda bulunan güvenlik açıklarını, siber tehditlerin en önemli kaynaklarından biri hâline getirmiştir. Güvenlik açıkları, sistemlerde, yazılımlarda veya bağımlılıklarda bulunan zafiyetlerdir ve saldırganlar tarafından sistemlere yetkisiz erişim sağlamak, veri sızdırmak veya hizmet kesintilerine yol açmak amacıyla istismar edilebilir (Aslan, Ö., Aktuğ, S. S., Ozkan-Okay, M., Yilmaz, A. A., & Akin, E., 2023). Bu güvenlik açıkları sadece bireysel kullanıcıların yanı sıra kritik altyapıları, finansal kurumları ve devlet sistemlerini de tehdit etmektedir (Kaur, D., Singh, B., & Rani, S., 2023). Güvenlik açıklarının zamanında tespit edilmesi, sınıflandırılması ve etkili şekilde önceliklendirilmesi, güçlü bir savunma stratejisinin oluşturulması için büyük önem taşımaktadır.

Siber saldırıların en büyük nedenlerinden biri sistemlerde bulunan güvenlik açıklarıdır. Yazılımsal hatalar, güncellenmemiş bağımlılıklar veya yanlış yetkilendirme gibi faktörler siber saldırganların istismar edebileceği ciddi zafiyetlere sebep olmaktadır. Bu bağlamda güvenlik açıklarının ciddiyetlerinin etkili bir şekilde değerlendirilmesi, yönetilmesi ve önceliklendirilmesi siber tehditlere karşı etkili bir savunma oluşturmanın en kritik adımlarından biridir.

1999'dan beri güvenlik açığını değerlendirmek için çeşitli güvenlik açığı skorlama sistemleri geliştirilmiştir (Liu, Q., Zhang, Y., Kong, Y., & Wu, Q., 2012). Bunların en yaygın kullanılanlarından biri olan Common Vulnerability Scoring System (CVSS), güvenlik açıklarının ciddiyetini belirlemek için standart bir sistem sunmaktadır (Holm, H., & Afridi, K. K., 2015). CVSS, yazılım güvenlik açıklarının ciddiyet derecelerini standartlaştırılmış bir şekilde değerlendirmek ve ölçmek üzere tasarlanmış skorlama sistemidir (Mell, P., Scarfone, K., & Romanosky, S., 2006). Bir güvenlik açığının etkisini hesaplamak için belirli metrik grupları kullanılarak 0 ile 10 arasında skor puanı oluşturulmaktadır. Bu skor, güvenlik açığı için statik bir değerlendirme sunarken tehditlerin gerçek dünyada istismar edilebilme olasılığına dair bir bilgi vermemektedir.

Bu eksiklikleri gidermek amacıyla 2019 yılında Exploit Prediction Scoring System (EPSS) önerilmiştir. EPSS, bir güvenlik açığının kamuya açıklandıktan sonraki dönemde istismar edilme olasılığını yüzde cinsinden tahmin eden bir model sunar (Mell, P., Scarfone, K., & Romanosky, S., 2006). Makine öğrenmesi algoritmaları ve büyük veri analizleri kullanan EPSS, sistem yöneticilerinin ve güvenlik uzmanlarının sınırlı kaynaklarını daha etkili kullanmasını sağlayacak dinamik ve tahmine dayalı bir bakış açısı sunmaktadır. CVSS'in sunduğu statik teknik değerlendirmeye karşılık EPSS daha dinamik ve tehdit odaklı bir önceliklendirme aracı olarak konumlanmaktadır.

Güvenlik açıklarının tanımlanması, izlenmesi ve yönetilmesi süreçlerinde kullanılan bir diğer önemli araç ise Open Source Vulnerabilities (OSV)'dir. OSV aracı özellikle açık kaynak yazılımlardaki bağımlılıklarda tespit edilen güvenlik açıklarını merkezi bir veri tabanında sunmakta ve bu açıkların hangi yazılım paket ve sürümlerini etkilediğini belirlemeye yardımcı olmaktadır (Google, n.d.). OSV sistemi, güvenlik açıklarındaki severity (CVSS) gibi ciddiyet skorlarını da vererek geliştiricilere güvenlik açıklarının yanı sıra bu açıkların taşıdığı risk düzeyi hakkında da bilgi sunulmaktadır (Google Open Source Blog, 2024). Bu araç, güvenlik açığı yönetimi süreçlerinin otomatikleştirilmesini ve güvenlik açıklarının hızlı bir şekilde tespit edilerek raporlanmasını mümkün kılarak, CVSS ve EPSS gibi sistemlerin etkin biçimde kullanılabileceği bir altyapı sunmaktadır.

Bu çalışmada, GitHub üzerinden seçilen açık kaynak 10 Java projesi tarayarak, CVSS ve EPSS skorlarının güvenlik açığı önceliklendirmedeki rollerini ele almayı amaçlamaktadır. CVSS'in güvenlik açıklarını standart bir şekilde değerlendirmesi ile EPSS'in bu açıkların istismar edilme olasılığını tahmin etmesi arasındaki farklara değinilecektir. OSV'nin bu skorlarla entegre çalışmasıyla elde edilen bulguların siber güvenlikte önceliklendirme stratejilerine katkısı ele alınacaktır. Böylece bu üç sistemin birlikte nasıl daha verimli kullanılabileceği konusunda pratik çıkarımlar elde edilmesi amaçlanmaktadır.

METARYEL VE YÖNTEM

Güvenlik açığı (vulnerability), bilgisayar sisteminde önemli güvenlik riskleri oluşturan ve sistemin saldırılara açık olmasına neden olan istismar edilebilir zafiyetlerdir (Han, Z., Li, X., Xing, Z., Liu, H., & Feng, Z., 2017). Güvenlik açıklarının standart bir şekilde tanımlanması için MITRE tarafından CVE (Common Vulnerabilities and Exposures) sistemi geliştirilmiştir (Haddad, A., Aaraj, N., Nakov, P., & Mare, S. F., 2023). Bu standart, güvenlik açıklarının kök nedenlerini belirleyerek, yazılım geliştiricileri ve güvenlik uzmanlarının daha güvenli sistemler tasarlamalarına ve mevcut sistemlerdeki zafiyetleri etkili bir şekilde tespit edip gidermelerine yardımcı olmaktadır. CWE, güvenlik zafiyetlerinin tanımlanması ve sınıflandırılmasında ortak bir dil ve standart sağlaması tutarlı bir iletişim ortamı oluşturmaktadır (Koscinski, V., & Mirakhorli, M., 2024). Örneğin, CWE-89 (SQL Injection) güvenlik açığı, kullanıcı girdilerinin doğrulanmadan SQL sorgularında kullanılması sebebiyle, veri tabanlarının yetkisiz erişime açık hale gelmesine neden olmaktadır (MITRE, n.d.). Bu tür bir güvenlik açığı, CVE-2023-56789 gibi benzersiz bir kimlik ile tanımlanarak tüm güvenlik platformları tarafından ortak bir standart çerçevesinde takip edilebilmektedir. CVE sınıflandırması, güvenlik açıklarının yalnızca tespit edilmesini değil, aynı zamanda kök nedenlerinin analiz edilerek benzer zafiyetlerin önlenmesini de sağlamaktadır. Scarfone ve Mell (Scarfone, K., & Mell, P., 2009) tarafından yapılan çalışmada, CVE sisteminin siber güvenlik topluluğuna büyük katkı sağladığı, ancak sadece bir kimliklendirme mekanizması sunduğu ve güvenlik açıklarının ciddiyeti hakkında doğrudan bir değerlendirme yapmadığı öne sürülmüştür. Bu eksikliği gidermek için CVSS ve EPSS gibi skorlama sistemleri geliştirilmiştir.

CVSS, yazılım ve donanım güvenlik açıklarının ciddiyetini değerlendirmek ve standart bir skorlama mekanizması sağlamak amacıyla geliştirilmiş bir sistemdir (Johnson, P., Lagerström, R., Ekstedt, M., & Franke, U., 2016). İlk olarak 2005 yılında tanıtılan CVSS, FIRST (Forum of Incident Response and Security Teams) tarafından yönetilmekte olup, güvenlik açıklarının teknik ve operasyonel etkilerini objektif bir şekilde değerlendirmeye yönelik bir sistem sunmaktadır. CVSS, 2007 yılında CVSS 2.0, 2015 yılında CVSS 3.0 ve 2019 yılında CVSS 3.1 olmak üzere çeşitli sürümlerle güncellenmiştir. En son sürümü olan CVSS 4.0, 2023'te yayımlanmış ve saldırı vektörleri, ayrıcalık seviyeleri ve güvenlik açıklarının sistem üzerindeki etkilerini daha detaylı ele alarak değerlendirme süreci iyileştirilmiştir.

CVSS'in genel amacı, güvenlik açıklarını standart bir şekilde değerlendirmek için ortak bir dil sunmaktır. Sistem, güvenlik açıklarını ilgili metrikler ile 0 ile 10 arasında puanlandırarak bu açıkların ciddiyetini belirlememizi sağlamaktadır. Puanlar, bir istismarın etkisini yaklaşık olarak belirleyen çeşitli ölçütlere sahip bir formüle göre hesaplanır. Bu sayede hangi güvenlik açığına öncelik verilmesi gerektiği belirlenir. CVSS, güvenlik açıklarını 3 ana metrik grubu üzerinden değerlendirir (Forum of Incident Response and Security Teams, n.d.-a). İlk olarak, güvenlik açığının temel özelliklerini analiz eden temel (base) skor, zafiyetin doğasını ve potansiyel etkisini belirler. Ardından, güvenlik açığının zaman içindeki değişkenliğini ve mevcut tehdit seviyesini ölçen zamansal (Temporal) skoru devreye girer. Son olarak, zafiyetin

belirli çevresel koşullar altındaki etkilerini değerlendiren çevresel (environmental) skor bulunur.

CVSS, siber güvenlik uzmanlarına belirli bir zafiyetin önemini ve aciliyetini değerlendirmede yardımcı olmak için bir çerçeve sağlamaktadır. Bu durum, siber güvenlik uzmanlarının sınırlı kaynaklarını en etkili şekilde kullanmalarına ve en kritik zafiyetlere öncelik vermelerine olanak tanır (Aksu, M. U., et al., 2017).

EPSS, bir güvenlik açığının yakın gelecekte istismar edilme olasılığını tahmin etmek için kullanılan bir skorlama sistemidir (Forum of Incident Response and Security Teams, n.d.-b). Özellikle tehdit istihbaratı ve saldırgan davranışlarını modelleyerek, güvenlik ekiplerine hangi güvenlik açıklarına öncelik vermeleri gerektiği konusunda yardımcı olmaktadır. FIRST tarafından geliştirilen EPSS, güvenlik açıklarının istismar edilme olasılığını tahmin etmek amacıyla büyük veri ve makine öğrenimi tekniklerinden yararlanır. EPSS, 2021 yılında ilk sürümünü yayımlamış ve 2023'te EPSS 3.0 sürümü ile güncellenmiştir (Forum of Incident Response and Security Teams., n.d.-c).

EPSS'nin temel amacı, güvenlik zafiyetlerinin kapatılma süreçlerini daha etkili hale getirmek ve sınırlı güvenlik kaynaklarını en yüksek orana sahip güvenlik açıklarına yönlendirmektir. EPSS, büyük miktarda veri kullanarak belirli bir güvenlik açığının istismar edilme olasılığını hesaplar. Bu veriler şunları içerebilir (Parla, R., 2024):

• Açık veri tabanlarından alınan güvenlik açıkları (CVE kayıtları)

• Saldırı teknikleri ve tehdit aktörleri hakkında veriler

• Exploit kitleri ve kötü amaçlı yazılım kampanyaları

• Siber tehdit istihbaratı raporları

Makine öğrenimi algoritmaları, bu verileri analiz edip, güvenlik açığının istismar edilme olasılığını belirler ve bir yüzdelik skor üretir (Hughes, C., & Robinson, N., 2024). EPSS skorları 0 ile 1 arasında yüzdelik olarak değişmektedir. 1'e yakın değerler, ilgili güvenlik açığının yüksek ihtimalle istismar edileceğini göstermektedir. CVSS ve EPSS, güvenlik açıklarını değerlendirmek için kullanılan ancak farklı amaçlara hizmet eden iki sistemdir. CVSS güvenlik açığının teknik ciddiyetini ve sistem üzerindeki potansiyel etkisini değerlendirmeye odaklanırken EPSS ise bir güvenlik açığının yakın gelecekte istismar edilme olasılığına yöneliktir. Bu iki sistem birlikte kullanılarak, güvenlik açıkları hem teknik şiddetlerine hem de gerçek dünya saldırı risklerine göre daha kapsamlı bir şekilde ele alınmaktadır.

OSV, Google tarafından açık kaynak projeleri için oluşturulmuş bir güvenlik açığı veri tabanı ve analiz aracıdır (Cybersecurity and Infrastructure Security Agency., n.d.). OSV aracının temel amacı açık kaynak yazılımlardaki bağımlılıklarda yer alan güvenlik açıklarının geliştiriciler tarafından daha kolay takip edilmesini ve bu açıkların etkili bir şekilde giderilmesini desteklemektir (Google Open Source Blog, 2021). CVE ve CWE gibi standartları referans alarak çalışan OSV, yazılım bileşenlerinin belirli sürümlerini hedef alarak hangi sürümlerin etkilendiğini ve hangi sürümlerde düzeltme yapıldığını detaylı bir şekilde sunar. Ayrıca, yazılım bağımlılıklarını analiz ederek projede kullanılan paketlerin bilinen zafiyetlere karşı savunmasız olup olmadığını otomatik olarak tespit edebilmektedir. OSV, EPSS gibi verileri destekleyen sistemlerle entegre çalışarak, sadece açıkların teknik detaylarını sunmakla kalmaz, aynı zamanda bu açıkların aktif olarak istismar edilme risklerini de değerlendirmeye yardımcı olur. OSV, hem yazılım geliştiricilerine hem de güvenlik ekiplerine açık kaynak güvenliğinde şeffaf, erişilebilir ve güncel bir çözüm sunmaktadır.

Bu çalışmada elde edilen bulgular doğrultusunda, güvenlik açıklarının önceliklendirilmesini otomatikleştiren ve CI/CD süreçlerine entegre edilebilen bir sistemin geliştirilmesi önerilmektedir. Bu sistem, güvenlik zafiyetlerini yalnızca tespit etmekle kalmayıp aynı zamanda bu zafiyetleri önceliklendirip gerçek zamanlı aksiyon alınmasını da mümkün kılarak yazılım güvenliğinde proaktif bir yaklaşım sunmayı hedeflemektedir. Sistem, yazılım geliştirme yaşam döngüsünün her aşamasında aktif olarak çalışarak, yeni bir bileşen eklendiğinde veya mevcut bileşenlerde bir güncelleme yapıldığında, projede kullanılan tüm bağımlılıkları otomatik olarak tarar ve bilinen güvenlik açıklarına karşı analiz eder. Bu sayede geliştiriciler, güvenlik risklerini erken aşamada tespit edebilir ve sistemin sunduğu önceliklendirme algoritmaları doğrultusunda kritik açıkları öncelikli olarak giderebilir.

Bu model kapsamında, CVE kayıtlarında henüz EPSS skoru atanmamış veya yayınlanmamış güvenlik açıkları için makine öğrenimi tabanlı tahminleme yöntemlerinin kullanılması planlanmaktadır. Geliştirilecek makine öğrenimi modelleri, geçmiş EPSS verileri, tehdit istihbaratı, exploit kitlerinin yaygınlığı, saldırgan davranışları gibi çeşitli veri kaynaklarını analiz ederek, eksik EPSS skorlarını tahmin edebilecektir. Böylece, güvenlik açıklarına yönelik alınacak aksiyonlarda yalnızca mevcut EPSS verileriyle sınırlı kalınmayacak, aynı zamanda modelin öngördüğü risk skorları da değerlendirmeye dâhil edilebilecektir. Bu yaklaşım, özellikle yeni yayınlanan ya da düşük görünürlüğe sahip açıkların da proaktif bir şekilde ele alınmasını sağlayacaktır.

Ayrıca, sistemin CISA tarafından yayınlanan Known Exploited Vulnerabilities (KEV) kataloğu ile entegre çalışması da önerilmektedir. Bu entegrasyon sayesinde yalnızca teorik olarak yüksek risk taşıyan zafiyetler değil, gerçek dünyada aktif olarak sömürülen açıklara da öncelik verilmesi mümkün olacaktır. KEV kataloğunda yer alan güvenlik açıklarının öncelikli olarak değerlendirilmesi, saldırganların güncel taktik ve tekniklerine karşı daha hazırlıklı olunmasını sağlayarak, sistem güvenliğinin artırılmasına katkı sunacaktır.

Tüm bu bileşenlerin birleşimiyle önerilen model, otomatikleştirilmiş analiz, makine öğrenimi temelli öngörüler ve güncel tehdit istihbaratını bir araya getirerek güvenlik zafiyetlerinin daha doğru, kapsamlı ve etkili bir şekilde yönetilmesini ve önceliklendirilmesini hedeflemektedir. Bu sistem, sadece yazılım geliştiriciler için değil aynı zamanda güvenlik ekipleri için de zaman ve kaynak tasarrufu sağlayarak, siber güvenlik süreçlerinin kalitesini artıracaktır.

Özetle, GitHub üzerinden alınan açık kaynak 10 java projesindeki bağımlılıklarda bulunan güvenlik açıkları OSV aracılığıyla çıkarılmış ve elde edilen CVE kimlikleri ile EPSS API kullanılarak istismar edilebilme olasılıkları elde edilmiştir. Elde edilen bulgular önceliklendirme için değerlendirilmiştir.

BULGULAR VE TARTIŞMA

Çalışmada önerilen modeli doğrulamak için, kaynak kodları GitHub'da bulunan popüler Java projeleri arasından ilk olarak 10 proje belirlendi. Deneysel olarak incelenen projeler Tablo 1'de listelenmiştir.

Tablo 1. Deneysel çalışma için seçilen projeler

No	Project Name	Stars	Fork	Repo URI
1	mall	80.6k	29.3k	https://github.com/macrozheng/mall
2	spring-petclinic	8.3k	25.6k	https://github.com/spring-projects/spring-petclinic
3	json-iterator	1.5k	526	https://github.com/json-iterator/java
4	JCSprout	27.1k	7.1k	https://github.com/crossoverJie/JCSprout
5	mall-swarm	12.4k	5.4k	https://github.com/macrozheng/mall-swarm
6	shopizer	3.7k	3.1k	https://github.com/shopizer-ecommerce/shopizer
7	hsweb-framework	8.4k	3k	https://github.com/hs-web/hsweb-framework
8	netty-socketio	7k	1.7k	https://github.com/mrniko/netty-socketio
9	socket.io-client-java	5.4k	979	https://github.com/socketio/socket.io-client-java
10	aviatorscript	4.8k	879	https://github.com/killme2008/aviatorscript

İncelenen projelerin güvenlik açıklarını belirlemek amacıyla OSV aracı ile projeler taratılmıştır. Değerlendirilen projelerde elde edilen CVE kimlikleri ile EPSS API aracılığı ile EPSS ve percentile değerleri elde edilmiştir. Elde edilen verilere ait bir güvenlik açığı analiz raporu Tablo 2 ‘sunulmuştur.

Tablo 2. Örnek güvenlik açığı analiz raporu

Name	CVE	Severity	EPSS	Percentile
com.fasterxml.jackson.core:jackson-databind	CVE-2020-8840	9.8	0.08	0.92
	CVE-2020-11112	8.8	0.11	0.93
	CVE-2020-35728	8.1	0.41	0.97
org.springframework:spring-core	CVE-2018-1271	5.9	0.92	1.0

Elde edilen bulgular doğrultusunda, severity (CVSS) skoru yüksek ancak EPSS skoru düşük olan güvenlik açıklarının pratikte istismar edilme olasılığının düşük olduğu gözlemlenmiştir. Buna karşılık, severity skoru düşük fakat EPSS skoru yüksek olan açıkların ise istismar riskinin daha yüksek olabileceği tespit edilmiştir. Percentile verileri incelendiğinde, EPSS skoru düşük ancak percentile değeri yüksek olan açıkların gerçek saldırılar arasında üst sıralarda yer aldığı, EPSS skoru yüksek ancak percentile değeri düşük olan açıkların ise gerçek saldırılar arasında alt sıralarda konumlandığı analiz edilmiştir. Bu bulgular, severity, EPSS ve percentile değerlerinin her biri ayrı ayrı değerlendirildiğinde güvenlik açığı önceliklendirmesinde sınırlı katkı sağladığını; ancak bu üç ölçütün birlikte analiz edilmesinin daha etkili ve verimli bir önceliklendirme süreci sunduğunu ortaya koymaktadır.

Analiz edilen projelerin bağımlılıklarındaki güvenlik açıklarının listesi Tablo 3’te sunulmaktadır.

Tablo 3. İncelenen projelerdeki güvenlik açıklarının sayısı

No	Project Name	Vulnerabilities
1	mall	24
2	spring-petclinic	7
3	json-iterator	64
4	JCSprout	61
5	mall-swarm	8
6	shopizer	10
7	hsweb-framework	5
8	netty-socketio	5
9	socket.io-client-java	4
10	aviatorscript	3

Deneysel çalışmanın bulguları, yalnızca CVSS veya yalnızca EPSS skorlarının ayrı ayrı incelenmesinin, güvenlik açıklarını önceliklendirme açısından yeterli olmadığını ortaya koymuştur. Elde edilen sonuçlar, bu iki metriğin birlikte değerlendirilmesinin, önceliklendirme sürecinde daha doğru ve etkili sonuçlar verdiğini göstermektedir. Özellikle CVSS skoru teknik şiddeti ortaya koyarken, EPSS skoru ilgili açığın gerçek dünyada istismar edilme olasılığına dair önemli bilgiler sunmaktadır.

Buna ek olarak, EPSS verileriyle birlikte sağlanan percentile değerinin de güvenlik açığı önceliklendirmede kritik bir rol oynadığı belirlenmiştir. Bu değer, bir güvenlik açığının bilinen diğer açıklar arasında göreli konumunu belirlemekte ve tehdit düzeyine dair daha somut bir perspektif sunmaktadır.

Dolayısıyla, güvenlik açıklarının etkili bir şekilde yönetilebilmesi için sadece bireysel skorlar değil, bu skorların bağlamsal yorumları ve karşılaştırmalı analizleri de dikkate alınmalıdır. Bu bütüncül yaklaşım, sınırlı kaynakların daha stratejik bir şekilde kullanılmasına ve daha güçlü bir siber güvenlik duruşunun sağlanmasına katkıda bulunacaktır.

SONUÇ VE ÖNERİLER

Çalışma kapsamında incelenen 10 açık kaynaklı Java projesinin bağımlılıkları ilk olarak OSV aracı ile çıkarılmıştır. Elde edilen CVE kimlikleri ile EPSS ve percentile verileri elde edilmiştir. Elde edilen veriler ayrı ayrı incelendiğinde güvenlik açığı önceliklendirmede yeterli bilgi sunmadığı gözlemlenmiştir. Bu bulgu bize güvenlik açığı önceliklendirme için yazılım geliştirme/dağıtım ortamlarında (CI/CD) entegre edilebilecek bir sistemin gerekliliğini göstermiştir.

Bu gereklilik CI/CD süreçleri için yeni bir modelin önerilmesine yol açmıştır. Önerilen bu model, bir güvenlik açığının önceliklendirilmesinde OSV ve EPSS API'dan elde edilen bulguların birlikte ele alınarak daha sağlıklı önceliklendirme yapılmasına olanak sağlayacaktır. Ayrıca Oluşturulacak modelin CISA KEV katoloğu ile entegre edilmesiyle, gerçek dünyada aktif olarak sömürülen açıklara öncelik verilerek sistem güvenliğinin artırılmasına katkı sunacaktır.

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SERVQUAL METHOD IN MEASURING SERVICE QUALITY AND RELATED LITERATURE REVIEW

HİZMET KALİTESİNİN ÖLÇÜLMESİNDE SERVQUAL METODU VE İLİŞKİLİ LİTERATÜR TARAMASI

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ÖZET

Günümüzde faaliyetlerini sürdürmekte olan çok sayıda perakende işi ile uğraşan şirket bulunmaktadır. Perakendecilik sektörü ile uğraşan büyük şirketler her geçen gün artmakta olan bu rekabetçi ortamda müşterilerini kaybetme korkusu ile karşı karşıya kalmaktadır. Perakendecilik alanında hizmet veren firmalar bu durum karşısında hizmet kalitesini her geçen gün daha da arttırmaya çalışmaktadır. Müşteri memnuniyetini ve bağlılığını arttırmak için işletmeler; tedarikçi seçiminden, tedarik edilen ürünün kalitesine ve zamanında teslim edilmesine kadar her detay ile tek tek ilgilenmektedirler. Müşterinin aradığı ürünü zamanında ve doğru bir şekilde yerinde bulması müşterinin firmaya olan güvenini arttırmaktadır. Bu nedenle firmalar tedarikçilerinin ürünü doğru şekilde ve doğru zamanda yerine ulaştırması konusunda çalışmalar yapmaktadır.

Müşteri odaklı hizmet yaklaşımı, hizmet kalitesi kavramını ön plana çıkarmıştır. Hizmet kalitesi, müşterinin ihtiyaçlarını tam olarak karşılamak ve karşılamak için yapılan tüm çalışmalar olarak tanımlanabilir. Hizmet sektöründe kalite, sektörde başarılı olmak için önemli bir unsurdur. Hizmet kalitesini ölçme yöntemlerinden biri olan SERVQUAL Yöntemi, müşteri beklentilerini ve hizmet algılarını yakalamak ve analiz etmek için kullanılan çok boyutlu bir araştırma yöntemidir. Bu çalışmada, hizmet kalitesini ölçmede içerdiği farklı boyutlar nedeniyle en çok tercih edilen yöntemlerden biri olan SERVQUAL yöntemi ile son 10 yılda yazılmış 33 yüksek lisans tezi incelenecek ve çalışmaların yıllara göre dağılımı ve uygulanan yöntemler ortaya konulacaktır.

Anahtar Kelimeler: Servqual, Müşteri Memnuniyeti, Hizmet Kalitesi

1. GİRİŞ

Geçmiş dönemlerde üretim yapan firmalar ürettikleri ürünlerin müşteriler tarafından doğrudan tüketildiğini bilmektedirler. Fakat sanayileşmenin hızla büyüyüp yayılması ürünlerin miktarını ve çeşitliliğini arttırmıştır. Bu durum işletmelerin ürünlerini pazarlayabilmeleri için müşteri odaklı hale gelmelerini sağlamıştır. Artık işletmeler ürünü sadece üretmekle kalmamakta bu ürünleri müşterilerin ihtiyaç ve isteklerine uyarlayarak müşteri portföyünü genişletmeye çalışmaktadırlar. Müşterileri ürün veya hizmeti almaya yönlendirebilmek için kalite kavramları ortaya atılmış ve bunlar üzerine işletmelerin yoğunlaşması kaliteli üretim ve kaliteli hizmet anlayışını ortaya koymuştur.

2. KALİTE NEDİR?

Kalite (Qualites) Latince "nasıl oluştuğu" anlamına gelen "qualis" kelimesinden gelmektedir. Buna göre kalite hangi ürün veya hizmet için kullanılıyorsa, onun ne olduğunu ifade etmeye yöneliktir. Oysa günümüzde kalite, daha çok üstünlüğü ve iyi oluşu ifade etmek için kullanılır. Bu nedenle kalite, kişisel değerleri içermektedir. (URL-1)

Firmaların uluslararası alanda yükselmesine yardımcı en önemli güç olarak görülen “Kalite” kavramı tanım olarak bir hizmet ya da ürünün tespit edilen veya gereksinim duyulacak ihtiyaçları karşılama kabiliyetine dayanan özelliklerin toplamıdır. Aynı zamanda ürün veya hizmetin iyi olup olmadığı konusunda müşterinin en son verdiği karar yani müşteri memnuniyetidir. (URL-1) Günümüzde sadece üretim alanında değil aynı zamanda hizmet alanında geniş bir yer edinen kalite kavramı işletmelerin artık tüm kaynaklarını kullanarak sisteme dahil olmaya çalıştığı bir süreç haline gelmiştir.

2.1.Üretim Kalitesi Nedir?

Üretim açısından kalite, dört temel yaklaşımda tanımlanabilir:

- Üretimi merkeze alan tanımlama: Bu yaklaşıma göre kalite; ihtiyaçlara cevap verme özelliğine sahip olmalıdır. Standartların ürünün üretiminde ne derece gerçekleştiği ile ilgilidir.
- Ürünü merkeze alan tanımlama: Ürünün içeriği ve içeriğindeki miktar ile ilgilidir.
- Değeri merkeze alan tanımlama: Müşterinin, tatmin olabileceği standartlarda, uygun bir fiyat ile sahip olabileceği ürün anlayışıdır.
- Kullanıcı-müşteriyi merkeze alan tanımlama: ürünün ‘amaca uygunluğunu kullanıcı/müşteri açısından değerlendirme. (Korkmaz, H.,C.,2016)

2.2.Hizmet Kalitesi Nedir?

Günümüzde, müşteri odaklı hizmet anlayışı, hizmet kalitesi kavramını ön plana çıkarmıştır. Hizmet kalitesi, müşterinin memnuniyeti ve ihtiyaçlarını tam anlamıyla sağlamak adına yapılan çalışmaların tümü olarak ifade edilebilir. Hizmetlerin soyut olması kalitesini değerlendirmeyi zorlaştırmaktadır. Bu durum hem müşteri hem de işletme adına dezavantajdır. İşletme, müşterinin hizmetlerin kalitesini nasıl değerlendirdiğini bilmezse, bunu hangi yönde kullanacağını da bilemez. Müşteri için de bu durum bazı zamanlarda pek kolay olmamaktadır. Çünkü hizmetlerin nitelinden dolayı kimi zaman değerlendirecek fiziksel bir özellik bulunamayabilir. Bu durumda, işletmenin temizliğine, fiziksel şartlarına, personelin dış görünümüne, ilgisine bakarak, hizmet kalitesini değerlendirir. İşletmenin, müşteri beklentilerinin ne kadarını karşılayabildiğinin bir ölçüsü hizmet kalitesinin karşılığıdır. (Korkmaz, H.,C.,2016)

2.2.1. Hizmet Kalitesinin Boyutları Nelerdir?

Geçmişi eski dönemlere dayanan ve herkes için ortak bir tanımı olmayan kalite kavramı tanımlamalarının farklı olmasından kaynaklı çok boyutlu bir kavram olarak ele alınmaktadır. Hizmet kalitesi boyutlarını ortaya koyan ve genel kabul gören en önemli çalışma Parasuraman, Zeithaml ve Berry (1985) tarafından yapılmıştır. Hizmet tipine bakılmadan hizmetler için temel kriterler oluşturulmuş ve bu kriterler on ana kategoride toplanmıştır. Bunlar; fiziksel özellikler, güvenilirlik, heveslilik, yeterlilik, nezaket, inanılırlık, güvenlik, ulaşılabilirlik, anlayış ve iletişimdir. (Kaya, Ş.,2014) Bu boyutları şöyle ifade edebiliriz:

2.2.1.1.Somut özellikler (Tangibles): Binaların, kullanılan teçhizatların, iletişim malzemelerinin ve personelin görünümü,

2.2.1.2.Güvenilirlik (Reliability): Vaat edilen hizmeti doğru olarak yerine getirme yeteneği,

2.2.1.3.Heveslilik (Responsiveness): Müşterilere yardım etme ve hızlı hizmet verme istekliliği,

2.2.1.4.Yeterlilik (Competence): Hizmeti yerine getirmek için gereken bilgi ve yeteneğe sahip olunması,

2.2.1.5.Nezaket (Courtesy): Müşteri ile ilişki kuran personelin nazik, saygılı ve samimi olması,

2.2.1.6.İnanılabilirlik (Credibility): Hizmet sunan kişinin güvenilir ve dürüst olması,

2.2.1.7.Güvenlik (Security): Tehlike, risk veya şüphenin olmaması,

2.2.1.8.Erişim (Access): Gerektiğinde iletişim kurma kolaylığı ve erişilebilirlik,

2.2.1.9.İletişim (Communication): Anlayabileceği dilden müşterinin bilgilendirilmesi ve sorunlarının dinlenmesi,

2.2.1.10. Empati (Empathy): Müşterileri ve ihtiyaçlarını tanımak için çaba sarf edilmesidir.

Hizmet kalitesini belirleyen ölçütlerden sonra, hizmet kalitesinin ölçümü şu formüle göre yapılmıştır:

Hizmet Kalitesi = (Beklenen hizmet kalitesi) – (Algılanan hizmet kalitesi)

Bu formüle göre; beklenen hizmet kalitesi, algılanandan büyük olursa, hizmet kalitesi tatmin edici değil; beklenen hizmet kalitesi algılanandan küçük olursa ideal hizmet kalitesi; eşit olması durumunda ise hizmet kalitesi tatmin edici demektir. (Korkmaz, H.,C.,2016).

2.2.2. Hizmet Kalitesi Modelleri

Hizmet kalitesinin ölçülebilmesi şirketlere hizmet kalitelerinin iyileştirilmesi ve geliştirilmesi yönünde en önemli adımı oluşturmaktadır. Çünkü mevcut durumu hakkında doğru veriler toplamayı başaran bir işletme eksiklerini bu doğrultuda tamamlamaya çalışarak hizmet kalitesini iyileştirip müşteri memnuniyeti ve müşteri potansiyelini arttırmada daha etkili ve hızlı önlemler alabilir. Nicel ölçütlerle ölçülebilen ürün kalite ölçümünden daha zor bir süreç olan hizmet kalitesi ölçümü için akademisyenler tarafından öncelikle hizmet kalitesini somut bir hale getirerek daha sonra üzerinde birtakım iyileştirmeler yapılması düşünülmüştür.

Literatürde yer alan ve hizmet kalitesini ölçmeye yarayan modellerden bazıları aşağıdaki gibidir. Bunlar;

- Algılanan hizmet kalitesi (GRÖNROOS modeli)
- SERVQUAL hizmet kalitesi modeli

- SERVPERF (Service Performance) hizmet kalitesi modeli vb.dir.

Bu çalışmada ise SERVQUAL Hizmet Kalitesi Modeli incelenmiş ve hizmet kalitesi ile ilgili 2014-2024 yılları arasında yapılan yüksek lisans çalışmaları incelenmiştir.

3. SERVQUAL HİZMET KALİTESİ MODELİ

SERVQUAL model, servis kalitesinin ve müşteri memnuniyetinin ölçüldüğü bir servis kalitesi ölçme metodudur. Hizmet Kalitesi (Service Quality) kelimelerinin kısaltması olan SERVQUAL Metodu müşteri beklentileri ve hizmet algılarını yakalayıp analiz etmek için kullanılan çok boyutlu bir araştırma yöntemidir. (URL-2)

3.1.SERVQUAL Tarihçesi

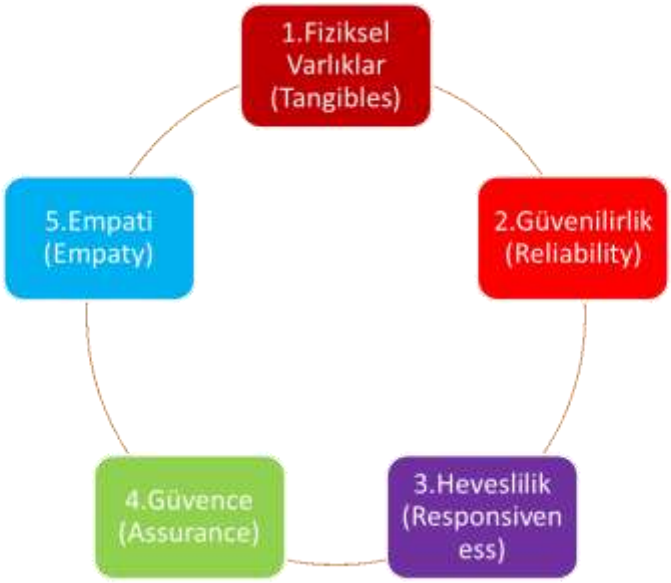
İlk olarak 1985 yılında Birleşmiş Milletlerdeki bir grup akademik araştırmacı olan A. Parasuraman, Valarie Zeithaml ve Leonard L. Berry tarafından ortaya atılan SERVQUAL Modeli anketi servis sektöründeki kaliteyi ölçmeyi amaçlamıştır. Ortaya atılan bu yöntem hizmet kalitesi araştırmalarında kullanılan ölçüm yöntemlerinde bir atılımı temsil ediyordu. Aracın tanısal değeri, ölçeğin (örn. araç veya anket) geliştirilmesine yönelik kavramsal çerçeveyi oluşturan hizmet kalitesi modeli tarafından desteklenir. Araç, çeşitli bağlamlarda ve kültürel ortamlarda yaygın olarak uygulanmış ve nispeten sağlam bulunmuştur. Hizmet kalitesi alanında baskın ölçüm ölçeği haline gelmiştir. SERVQUAL'a ve sayısız bağlam-özgü uygulamasına olan uzun süredir devam eden ilgiye rağmen, araştırmacılardan bazı eleştiriler almıştır. (URL-2)

Hizmet Kalitesi literatüründe SERVQUAL Metodu, literatüründe en kapsamlı çalışmalardan biridir ve yaratıcıları geliştirdikleri yöntemin evrensel olarak geçerli olduğunu ve küçük değişikliklerle her sektöre uygulanabileceğini çünkü en temel hizmet kalitesi boyutlarını tanımladığını ileri sürmektedirler.

Parasuraman ve arkadaşları hizmet kalitesini ölçmek için 22 maddeden oluşan bir ölçme yöntemi geliştirmişlerdir. Bu 22 maddelik sorudan oluşan anket hizmet kalitesi ölçülürken ilk aşamada tüketicinin hem hizmet aldığı işletmeden beklentisini ölçerken kullanılıyor hem de aynı sorular müşterinin o işletmeden hizmet alırken ki algısını ölçerken kullanılıyor. Ölçekte “tamamen katılıyorum” ile “kesinlikle katılmıyorum” arasında değişen 7’li Likert Ölçeği kullanılmıştır. İlk aşama olarak Parasuraman ve arkadaşları hizmet kalitesini tanımlamaya daha sonra ise bu terimi etkileyen faktörleri bulup bunları ölçülebilir hale getirecek bir model geliştirmeye çalışmışlardır.

SERVQUAL araştırmasında elde edilen verilerle yapılan istatistiksel analizler iki önemli noktayı daha ortaya çıkarmıştır. Birincisi, on hizmet kalitesi ölçütünün bazılarının kendi aralarında kayda değer bir şekilde bağlantılı olduğu ve bunları kapsayacak daha geniş bir ölçüte gereksinim duyulduğudur. Bu doğrultuda ölçütler kendi aralarında gruplandırıldıklarında 5 hizmet kalitesi ortaya çıkmıştır. Bunlar;

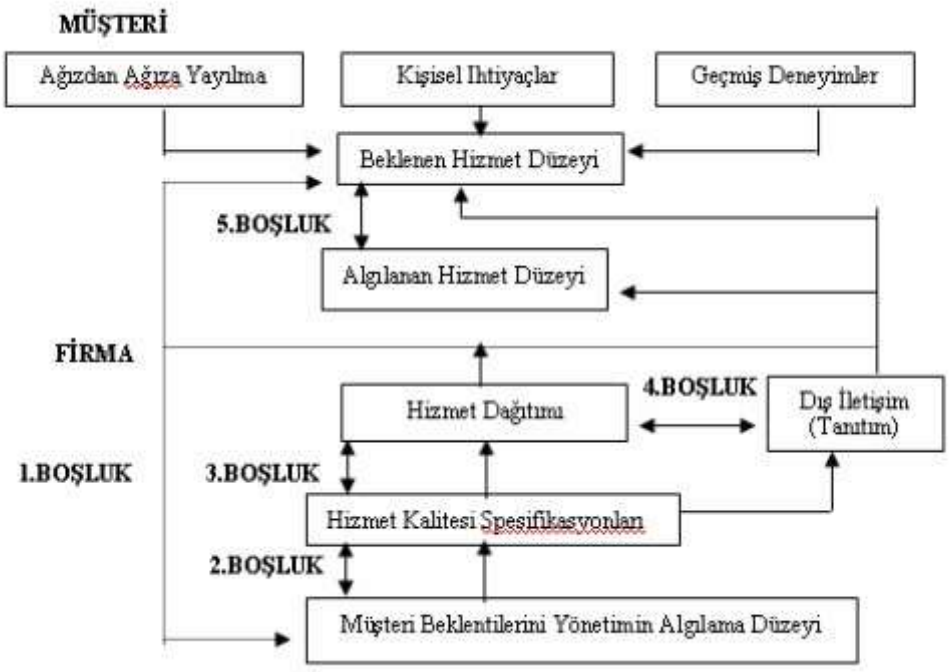
1. Fiziksel Varlıklar
2. Güvenilirlik
3. Heveslilik
4. Güvence
5. Empati



Şekil 1 Hizmet Kalite Ölçütleri

Parasuraman ve arkadaşları ilk dördü arka planda gerçekleşen ve beşincisi ise müşteri ile yüz yüze olan hizmetlerde ortaya çıkan toplamda 5 adet boşluk (gap) belirlemişlerdir. Bu boşluklar hizmet kalitesini etkileyen faktörleri anlaşılabilir kılmıştır. Kalite problemlerinin sebep olduğu 5.boşluk, müşterinin hizmet beklentisiyle algılaması arasındaki farktır. Bu boşluk hizmet kalitesi olarak tanımlanmıştır. Çizelge 3.1. de "Boşluklar Modeli" gösterilmektedir.

Tablo 1 Boşluklar Modeli



1.Boşluk: Müşteri beklentileri ve yönetimin müşteri beklentilerini algılaması arasındaki fark.

2.Boşluk: Yönetimin müşteri beklentilerini algılaması ve hizmet kalitesi standartları arasındaki fark.

3.Boşluk: Hizmet kalitesi standartları ve hizmetin sunumu arasındaki fark (hizmet performansı farkı).

4.Boşluk: Hizmetin sunumu ve dış çevre ile iletişimler arası fark.

5.Boşluk: Beklenen hizmet ve algılanan hizmet arasındaki fark.

Parasuraman, Zeithaml ve Berry (1988) yukarıda kısaca açıklanan ilk dört boşluğun, SERVQUAL modelinin temelini oluşturan beşinci boşluğu meydana getiren başlıca nedeni olduğunu göstermiştir. Bu boşluk olumlu olduğunda yani kişilerin algıladığı hizmet beklediği hizmete eşit veya beklediği hizmetten yüksek olduğu durumlarda kaliteden söz edilebilir. Algıladıkları hizmetin beklentilerinin altında olması ise kalitesizliğe yol açar.

4. HİZMET KALİTESİ ÖLÇÜMÜ İÇİN YAPILAN YÜKSEK LİSANS ÇALIŞMALARI

Bu çalışmada ise SERVQUAL Hizmet Kalitesi Modeli incelenmiş ve hizmet kalitesi ile ilgili 2014-2024 yılları arasında yapılan yüksek lisans çalışmaları incelenmiştir. Yapılan inceleme sonucunda Hizmet Kalitesi ile ilgili yapılan yüksek lisans tezleri yazar, yıl, çalışma adı, optimal yöntem, üniversitenin adı ve uygulanan alan olmak üzere kategorize edilerek Tablo 4.1. de detaylı hale getirilmiştir.

Tablo 2. Hizmet Kalitesi ile İlgili Yapılan Yüksek Lisans Tezleri (2014-2024)

YAZAR	***YIL***	***ÇALIŞMANIN ADI***	***OPTİMAL YÖNTEM***	***ÜNİVERSİTENİN ADI***	***UYGULANAN ALAN***
Büşra DEMİREL	*2024*	*Veri Zarflama Analizi İle Etkinlik Ölçümü Ve SERVQUAL Modeli İle Hizmet Kalitesi Değerlendirme: Bir Kargo Firmasında Uygulama*	*Veri Zarflama+ SERVQUAL*	*Gazi Üniversitesi*	*Lojistik*
Rukiye Betül OFLAZ	*2023*	*Özel Bir Fizik Tedavi Kliniğinde Hizmet Kalitesinin Servqual Yöntemiyle Ölçülmesi*	*SERVQUAL*	*Kırıkkale Üniversitesi*	*Sağlık Sektörü*
Seda KAYA	*2023*	*Otomobil satışı yapan alışveriş sitelerinin bulanık çok kriterli karar verme yöntemleri kullanılarak E-SQUAL'e dayalı değerlendirilmesi*	*E-S-QUAL+Pisagor Bulanık AHP+Pisagor Bulanık TOPSİS*	*Ondokuz Mayıs Üniverstesi*	*E-Alışveriş*
Serap TAŞKIRAN KÜÇÜKÖZKUL	*2023*	*Satış sonrası hizmet kalite kriterlerinin kalite fonksiyon yayılım metodolojisi kullanılarak yeniden değerlendirilmesi*	*KFY+SERVQUAL+ AHP*	*Dokuz Eylül Üniversitesi*	*Satış Sonrası Müşteri Memnuniyeti*
Ömer Faruk PARMAKSIZ	*2022*	*Kargo Şirketlerinin Faaliyetleri Sırasında Oluşan Hizmet Kalitesinin Servqual Model İle Ölçülmesi*	*SERVQUAL*	*Harran Üniversitesi*	*Lojistik*
Duygu DEMİR	*2022*	*Havalimanı Hizmet Kalitesinin Servqual Modeli İle Ölçülmesi Ve Değerlendirme Sorularının Apriori Algoritması İle İlişki Analizi*	*SERVQUAL+APRİORİ Algoritması*	*İstanbul Üniversitesi-Cerrahpaşa*	*Havacılık Sektörü*
Şeyma AKTÜYLÜ	*2022*	*Yükseköğretimde Uzaktan Eğitimin İki Aşamalı Ve Karşılaştırmalı Performans Analizi*	*SWOT Analizi+ Bulanık SERVQUAL+ Bulanık TOPSIS +ANP*	*Atatürk Üniversitesi*	*Eğitim Sektörü*
Ömer Cem BOZKIR	*2022*	*Fermatean bulanık sayılar kullanarak kalite fonksiyon göçerimi analizi: Telekomünikasyon sektöründe örnek bir uygulama*	*Fermatean Bulanık Set+KFY+Kalite Evi*	*Yıldız Teknik Üniversitesi*	*Telekomünikasyon*
Nur Bengi ERDEM	*2021*	*Servperf Modeli İle Kurs Hizmetlerinin Kalitesini Ölçmeye Yönelik Bir Uygulama*	*SERVPERF*	*Kırıkkale Üniversitesi*	*Eğitim Sektörü*
Kübra TOPAL	*2021*	*Ticari paket yazılım üreten orta ölçekli bir yazılım firmasında çok kriterli karar verme (ÇKKV) yöntemi kullanılarak hizmet kalitesinin arttırılması ve müşteri memnuniyetinin ölçülmesi*	*AHP*	*Beykent Üniversitesi*	*Yazılım Paketleri*
İnci Hüma ÇENDİK	*2020*	*Eğitim Sektöründe Faktör Analizi Temelli Kalite Evi Uygulaması*	*Keşfedici Faktör Analizi+ SERVQUAL+Kalite Evi*	*Eskişehir Osmangazi Üniversitesi*	*Eğitim Sektörü*
Hasibe Berfu DEMİR	*2019*	*Bir Taşımacılık Şirketinde Servis Modülerliği ile Müşteri Memnuniyeti*	*SERVQUAL*	*İstanbul Üniversitesi-Cerrahpaşa*	*Ulaşım Sektörü*

Merve Gizem KARŞI	*2019*	*Sağlık Sektöründe Hizmet Kalitesi Ölçüm Yöntemlerinin Değerlendirilmesi ve Bir Hastanede Uygulanması*	*SERVQUAL*	*Eskişehir Osmangazi Üniversitesi*	*Sağlık Sektörü*
Elif ÇETİN	*2019*	*Sağlık Hizmetlerinde Modülerlik Ve Müşteri Memnuniyeti*	*SERVQUAL*	*İstanbul Üniversitesi-Cerrahpaşa*	*Sağlık Sektörü*
Selen RUPİÇ SANCAKLI	*2019*	*Lojistik hizmetlerinde müşteri memnuniyet seviyesinin bulanık bilişsel haritalama yöntemi ile değerlendirilmesi*	*Bulanık Bilişsel Haritalama*	*Galatasaray Üniversitesi*	*Lojistik*
Sultan ALTUN	*2019*	*Elektrik dağıtım hizmetleri sunan bir işletmede müşteri memnuniyetini etkileyen faktörlerin yapısal eşitlikmodellemesi ile belirlenmesi*	*Yapısal Eşitlik Modellemesi(SEM)*	*Kırıkkale Üniversitesi*	*Elektrik Dağıtım İşletmesi*
Büşra KORKMAZ	*2019*	*Elektrik dağıtım şirketleri performanslarının analitik hiyerarşi süreci ve veri zarflama analizi ile değerlendirilmesi*	*AHP- Veri Zarflama*	*Hacettepe Üniversitesi*	*Elektrik Dağıtım İşletmesi*
Burak SEVİM	*2019*	*Tedarik zinciri yönetiminde hizmet kalitesi açısından müşteri ilişkileri yönetimi faaliyetleri ve bir üretim işletmesi örneği*	*Customer Relationship Management(CRM)*	*İstanbul Üniversitesi-Cerrahpaşa*	*Otomotiv Yan Sanayi*
Baranalp ÖZKAN	*2019*	*Toplu taşımada hizmet kalitesinin istatistiksel analizi: İstanbul Metrosu müşteri memnuniyeti araştırması*	*Faktör Analizi -T-testi*	*Yıldız Teknik Üniversitesi*	*Ulaşım Sektörü*
Gonca CENGİZ	*2019*	*Bütünleşik yeni bir yaklaşım ile havayolu hizmet kalitesinin cinsiyetler açısından değerlendirilmesi*	*Entropi Ağırlıklı Bulanık EDAS+Entropi Ağırlıklı Bulanık VİKOR*	*Başkent Üniversitesi*	*Havacılık Sektörü*
Ceren ÜNLÜKAL	*2019*	*Konaklama işletmelerinin hizmet kalitesinin değerlendirilmesi için sezgisel bulanık AHP ve TOPSIS yöntemlerinin kullanılması*	*AHP+TOPSİS*	*Eskişehir Teknik Üniversitesi*	*Otel İşletmeleri*
Uğur ŞELECİ	*2018*	*Türk Havacılık Sektöründe Hizmet Kalitesinin Analizi*	*SERVQUAL+Yapısal Eşitlik Modellemesi (SEM)*	*Bahçeşehir Üniversitesi*	*Havacılık Sektörü*
Mehmet SAVAŞ	*2018*	*Bir Aile Sağlığı Merkezinde Hizmet Kalitesinin Servqual ve Regresyon Analizi ile Değerlendirilmesi*	*SERVQUAL+ Çok Değişkenli Regresyon Analizi*	*Eskişehir Osmangazi Üniversitesi*	*Sağlık Sektörü*
Leman İnci ÇANAKÇI YÜKSEL	*2018*	*Sağlık sektöründe hizmet kalitesinin çok ölçütlü karar verme yöntemleri ile değerlendirilmesi: Ankara'da bir uygulama*	*AHP+Bulanık TOPSİS*	*Gazi Üniversitesi*	*Sağlık Sektörü*
Beyhan ALBAYRAK	*2018*	*Hizmet kalitesinin servperf metodu ile ölçümü ve sonuçlarının doğrulayıcı faktör analizi ile desteklenmesi kırıkkale üniversitesi Tıp Fakültesi uygulaması*	*SERVPERF+Doğrulayıcı Faktör Analizi*	*Kırıkkale Üniversitesi*	*Sağlık Sektörü*

Semih KANSU	*2017*	*Servis Sistemleri İçin Bütünleşik Servqual - Kalite Fonksiyon Yayılımı - Hata Türleri Ve Etkileri Analizi Yaklaşımı ve Bir Hastane Uygulaması*	*SERVQUAL+KFY+ HTEA*	*Yıldız Teknik Üniversitesi*	*Sağlık Sektörü*
Gülin BAHÇİVAN	*2017*	*Yüksek öğretim enstitülerinde kalite ölçümü*	*SERVQUAL-Yapısal Eşitlik Modellemesi(SEM)*	*Bahçeşehir Üniversitesi*	*Eğitim Sektörü*
Hakkı Can KORKMAZ	*2016*	*Atık Su Arıtma Tesislerinin Hizmet Kalitesinin Servqual Tekniğiyle Ölçülmesi: Adana ve Mersin Organize Sanayi Bölgelerinde Bir Uygulama*	*SERVQUAL*	*Toros Üniversitesi*	*Atık su arıtma tesisleri*
Gizem ERDİNÇ	*2016*	*Otel işletmelerinde hizmet kalitesinin değerlendirilmesi için bulanık çok kriterli karar verme yönteminin kullanılması*	*Bulanık ÇKKV(Bulanık Moora)*	*Erciyes Üniversitesi*	*Otel İşletmeleri*
Ebru KASNAK	*2015*	*Kadın Girişimciliğinin Teşviki Amacıyla Uygulanacak Destek Programının Teknik Gereksinimlerinin Kalite Fonksiyon Göçerimi Yaklaşımı İle Belirlenmesi*	*SERVQUAL+KFY*	*Anadolu Üniversitesi*	*TR33 bölgesinde (Afyonkarahisar, Manisa, Kütahya ve Uşak illerinde)*
Mahmut Sami SİVRİ	*2015*	*Kalite fonksiyonu açılımı yaklaşımıyla mobil kampanya uygulaması tasarımı / Mobile campaign application design with quality function deployment approach*	*KFY*	*İstanbul Teknik Üniversitesi*	*Mobil Uygulama Tasarımı*
Şeyda KAYA	*2014*	*Yatan Hasta Kalite Algısının SERVQUAL Temelli Analiz ve Kalite Fonksiyonu Yayılımı İle Değerlendirilmesi: Eskişehir Devlet Hastanesi'nde Bir Uygulama*	*SERVQUAL+KFY+ AHP*	*Eskişehir Osmangazi Üniversitesi*	*Sağlık Sektörü*
Hamid TALEBİ	*2014*	*KFY ve bulanIk-analitik hiyerarşi süreCi yöntemleri fitnes merkezinde hizmet kalitesini geliştirmek için kullanımı*	*Belirsiz-AHP+ SERVQUAL+ KFY*	*Bahçeşehir Üniversitesi*	*Fitness Salonları*

2014-2024 yılları arasında hizmet kalitesi için yapılan 33 adet yüksek lisans tezinin yıllara göre dağılımı şekil 2. de gösterilmiştir. İncelenen dağılımda hizmet kalitesi ile ilgili her sene düzenli çalışmalar yapıldığı ama 2019 yılında bu çalışmaların en fazla olduğu gözlemlenmiştir.



Şekil 2. Çalışmaların Yıllara Göre Dağılımı

Tablo 3. Çalışmalarda Kullanılan Çözüm Yöntemleri

Model Adı	***Yöntemler***	***Toplam Adet***	***Yüzde(%)***
Tek Çözüm Yöntemi Kullanılarak Yapılan Çalışmalar	*AHP*	*13*	*39,39*
	Bulanık Bilişsel Haritalama		
	Bulanık ÇKKV(Bulanık Moora)		
	Customer Relationship Management(C		
	KFY		
	SERVPERF		
	SERVQUAL		
	Yapısal Eşitlik Modellemesi(SEM)		
Hibrit Yöntemler Geliştirilerek Yapılan Çalışmalar	*AHP- Veri Zarflama*	*20*	*60,61*
	AHP+TOPSİS		
	AHP-Bulanık TOPSİS		
	Belirsiz-AHP+ SERVQUAL+ KFY		
	Entropi Ağırlıklı Bulanık EDAS+Entro		
	E-S-QUAL+Pisagor Bulanık AHP+P		
	Faktör Analizi -T-testi		
	Fermatean Bulanık Set+KFY+Kalite		
	Keşfedici Faktör Analizi+ SERVQUA		
	KFY+SERVQUAL+AHP		
	SERVPERF-Doğrulayıcı Faktör Anal		
	SERVQUAL+ Çok Değişkenli Regre		
	SERVQUAL+APRİORİ Algoritması		
	SERVQUAL+KFY		
	SERVQUAL+KFY+ HTEA		
	SERVQUAL+KFY+AHP		
	SERVQUAL+Yapısal Eşitlik Modelle		
	SERVQUAL-Yapısal Eşitlik Modelle		
	SWOT Analizi+ Bulanık SERVQUAL		
	Veri Zarflama+ SERVQUAL		
Toplam		*33*	*100,00*



Şekil 3. Kullanılan Çözüm Yöntemi Modelleri



Şekil 4. Çalışanların Uygulama Alanları

5. SONUÇ VE ÖNERİLER

Küreselleşmenin ve dijitalleşmenin hızla artış gösterdiği ve gündelik hayatın içine doğrudan girdiği günümüzde şirketler, ürettikleri ürün veya hizmetlerin müşteriler tarafından tercih edilebilirliğinin artması için sadece kaliteli ürün üretmekle kalmıyor; aynı zamanda bu ürünlerin müşterilere ulaştığı andaki müşteri memnuniyetine de dikkat çekmektedirler. Ürünü müşteriye sunarken müşterinin beklentisi ile algıladığı hizmeti birbirine denk getirmek için gerekli yatırımları yaparak bir adım daha öne geçmeye çalışmaktadırlar. Bu doğrultuda yatırımlarını bu yöne çekerek müşteri memnuniyetini arttırmak ve hizmet kalitesini ölçmek ilk öncelikler arasına yükselmiştir.

Bu çalışmada ise hizmet kalitesi konusu üzerine yapılan yüksek lisans tezlerinin hangi alanlarda ve hangi yöntemlerle yapıldığı incelenmiş olup hizmet kalitesi ölçümünde istatistiksel ve çok kriterli karar verme yöntemlerinin kullanımının yüksek oranda olduğu, aynı zamanda çalışma alanları incelendiğinde en fazla sağlık daha sonra havacılık, lojistik ve eğitim alanlarında çalışmaların yapıldığı gözlemlenmiştir.

Bu çalışmanın amacı; hizmet kalitesi ölçümünde yapılan 2014-2024 yılları arasındaki yüksek lisans çalışmalarının bir arada sunularak kullanılan metotların ve çalışma alanlarının mevcut durumunu istatiksel olarak ortaya koymaktır.

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INTELLIGENT OPTIMIZATION OF AIRLINE TICKET PRICES VIA A GENETIC ALGORITHM-BASED DYNAMIC APPROACH

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ABSTRACT

Today, dynamic pricing plays a critical role in the airline transportation sector in terms of gaining a competitive advantage and maximizing revenue. Airline ticket prices are determined by many variables such as flight time, class, number of transfers, occupancy rate, and boarding/arrival times, which causes traditional pricing methods to be inadequate. In this context, this complex problem structure, which includes multivariate and uncertainty, reveals the need for more flexible, learning, and optimizing models. In this study, a Genetic Algorithm based artificial intelligence model was developed for the dynamic optimization of airline ticket prices, and the performance of this model on price estimation was examined. The model aims to determine the most appropriate price level by considering various parameters related to the flight. This structure, which was developed based on Genetic Algorithm, one of the metaheuristic methods, was modelled over basic GA components such as selection, crossover, mutation, and fitness functions. In addition, different parameter configurations were tried, and the most appropriate GA structure was determined. The data set used consists of approximately 11,000 flight information belonging to different airline companies. The application results show that Genetic Algorithms provide higher accuracy, especially in multivariate and nonlinear problems, compared to classical statistical and regression-based models. This study not only presents an innovative approach to dynamic pricing processes in the aviation sector but also demonstrates the applicability of Genetic Algorithms to real-world problems. The findings show that this approach is not limited to airline ticket pricing only but can also be an effective solution method in other sectors requiring similar optimization.

Keywords: genetic algorithm, dynamic pricing, flight ticket, optimization, artificial intelligence, meta-heuristic methods.

INTELLIGENT OPTIMIZATION OF AIRLINE TICKET PRICES VIA A GENETIC ALGORITHM-BASED DYNAMIC APPROACH

ÖZET

Günümüzde dinamik fiyatlandırma, havayolu taşımacılığı sektöründe rekabet avantajı elde etmek ve geliri maksimize etmek açısından kritik bir rol oynamaktadır. Uçak bileti fiyatları; uçuş saati, sınıf, aktarma sayısı, doluluk oranı ve biniş/varış saatleri gibi birçok değişkene bağlı olarak belirlenmekte olup, bu durum geleneksel fiyatlandırma yöntemlerini yetersiz kılmaktadır. Bu bağlamda çok değişkenli ve belirsizlik içeren bu karmaşık problem yapısı, daha esnek, öğrenen ve optimize eden modellere olan ihtiyacı ortaya koymaktadır. Bu çalışmada, uçak bileti fiyatlarının dinamik olarak optimize edilmesi amacıyla Genetik Algoritma tabanlı bir yapay zeka modeli geliştirilmiş ve bu modelin fiyat tahmini üzerindeki performansı incelenmiştir. Model, uçuşa ilişkin çeşitli parametreleri dikkate alarak en uygun fiyat seviyesini belirlemeyi amaçlamaktadır. Meta-sezgisel yöntemlerden biri olan Genetik Algoritma temel alınarak geliştirilen bu yapı; seçim, çaprazlama, mutasyon ve uygunluk fonksiyonları gibi temel GA bileşenleri üzerinden modellenmiştir. Ayrıca farklı parametre yapılandırmaları denenmiş ve en uygun GA yapısı belirlenmiştir. Kullanılan veri seti, farklı havayolu şirketlerine ait yaklaşık 11.000 uçuş bilgisine dayanmaktadır. Uygulama sonuçları, Genetik Algoritmaların özellikle çok değişkenli ve doğrusal olmayan problemler karşısında klasik istatistiksel ve regresyon tabanlı modellere göre daha yüksek doğruluk sağladığını göstermektedir. Bu çalışma, yalnızca havacılık sektöründeki dinamik fiyatlandırma süreçlerine yenilikçi bir yaklaşım sunmakla kalmayıp, aynı zamanda Genetik Algoritmaların gerçek dünya problemlerine uygulanabilirliğini de ortaya koymaktadır. Elde edilen bulgular, bu yaklaşımın yalnızca uçak bileti fiyatlandırması ile sınırlı olmadığını, benzer optimizasyon gerektiren diğer sektörlerde de etkili bir çözüm yöntemi olabileceğini göstermektedir.

Anahtar Kelimeler: genetik algoritma, dinamik fiyatlandırma, uçak bileti, optimizasyon, yapay zekâ, meta-sezgisel yöntemler.

GİRİŞ

Bu çalışmada, uçak bilet fiyatlarının dinamik olarak optimize edilmesi amacıyla Genetik Algoritma tabanlı bir yapay zekâ modeli geliştirilmiştir. Model; uçuş zamanı, sınıfı, kalkış-varış şehirleri, aktarma sayısı gibi çeşitli parametreleri dikkate alarak en uygun bilet fiyatlarını belirlemeyi hedeflemektedir. Yaklaşık 11.000 uçuş bilgisinden oluşan veri setiyle yapılan uygulamalarda, metasezgisel algoritmalardan biri olan Genetik Algoritma'nın klasik yöntemlere göre daha yüksek doğruluk sağladığı ve karmaşık fiyatlandırma problemlerinde başarılı sonuçlar ürettiği görülmüştür. Bu çalışma, dinamik fiyatlandırma stratejileri kapsamında havacılık sektörü başta olmak üzere birçok alanda metasezgisel algoritmaların optimizasyon problemleri için etkili bir çözüm sunabileceğini ortaya koymaktadır. Metasezgisel algoritmalar, doğadan esinlenerek geliştirilen ve karmaşık optimizasyon problemlerine yaklaşık ama etkili çözümler üretebilen yöntemlerdir. Bu algoritmalar, problem alanı hakkında doğrudan bilgiye ihtiyaç duymadan, geniş çözüm uzaylarında yüksek başarı elde edebilmektedir. Genetik Algoritma, Parçacık Sürü Optimizasyonu ve Benzetilmiş Tavlama gibi algoritmalar bu gruba dahildir. Özellikle uçak bilet fiyatlandırması gibi çok kriterli, doğrusal olmayan yapılar içeren problemlerde, metasezgisel algoritmalar esneklik, uyarlanabilirlik ve performans açısından klasik yöntemlere göre üstünlük sağlamaktadır. Genetik algoritmalar, biyolojik evrim sürecinden ilham alınarak geliştirilmiş optimizasyon yöntemleridir. Her birey, çözüm önerisini temsil eden bir kromozom olarak modellenir ve bu kromozomlar belirli genlerden oluşur. Algoritmanın temel yapısı; seçme, çaprazlama ve mutasyon olmak üzere üç ana işlemden oluşur. Seçme aşamasında, uygunluk değeri yüksek olan bireyler yeni nesillere taşınır. Çaprazlama ile ebeveyn bireylerden yeni bireyler türetilir ve çeşitlilik sağlanır. Mutasyon işlemi ile bireylerin bazı genleri rastgele değiştirilerek yerel minimumlara takılma riski azaltılır. Bu süreç, hedeflenen başarıya ulaşılana kadar tekrar edilir. Genetik algoritmada, gen bireyin özelliklerini taşıyan temel birimdir ve genler, kromozomlar adı verilen diziler hâlinde bir araya gelir. Genotip, kromozomlarda bulunan gen topluluğunu; fenotip ise bu genlerin dışa vurmuş hâlini ifade eder. Alleller, genlerin alabileceği farklı değerlerdir ve genlerin yer aldığı konumlara lokus denir. Popülasyon, gen havuzundaki bireylerin tümünü temsil eder. Uygunluk fonksiyonu, bireylerin çevreye ne kadar uyumlu olduğunu ölçerken, seleksiyon süreci popülasyondan en uygun bireylerin seçilmesini sağlar; bu seçim, daha iyi çözümlerin çoğalmasını hedefler. Mutasyon ise genetik çeşitliliği artırmak ve algoritmanın yerel çözümlere takılmasını önlemek için bireylerde rastgele küçük değişiklikler yapılmasıdır. Bu kavramlar, genetik algoritmanın temel yapı taşlarını oluşturur ve optimizasyon problemlerinin çözümünde etkin biçimde kullanılır.

MATERYAL VE YÖNTEMLER

Genetik algoritmalar, biyolojik evrim süreçlerinden esinlenerek optimize çözümler üreten yöntemlerdir. Bu projede kromozomlar A (Airline_Score katsayısı), B (Duration_Minutes katsayısı), C (Stop_Count katsayısı) ve D (Info_Numeric katsayısı) genlerinden oluşmakta olup her kromozom bir aday çözümü temsil etmektedir. Kromozomlar genellikle 0-1 kodlama, permütasyon veya reel kodlama yöntemleriyle ifade edilir. 0-1 kodlama en yaygın yöntemdir ve çaprazlama ile mutasyon işlemlerine elverişlidir; ancak uzun kromozomlarda hesaplama ve hafıza açısından zorluk yaratabilir. Permütasyon kodlama, özellikle sıralama ve rotalama problemleri için uygundur. Reel kodlama ise gerçek değerlerle gösterim sağlar ve kısıtlı optimizasyon problemlerinde tercih edilir.

Popülasyon, çözüm adaylarından oluşan bir grup olarak tanımlanır ve bu projede büyüklüğü 1000 olarak belirlenmiştir. Küçük popülasyonlar hızlı çalışmakla beraber çeşitlilik azalır ve yerel minimuma takılma riski artar. Büyük popülasyonlar ise daha fazla çeşitlilik sağlar ve

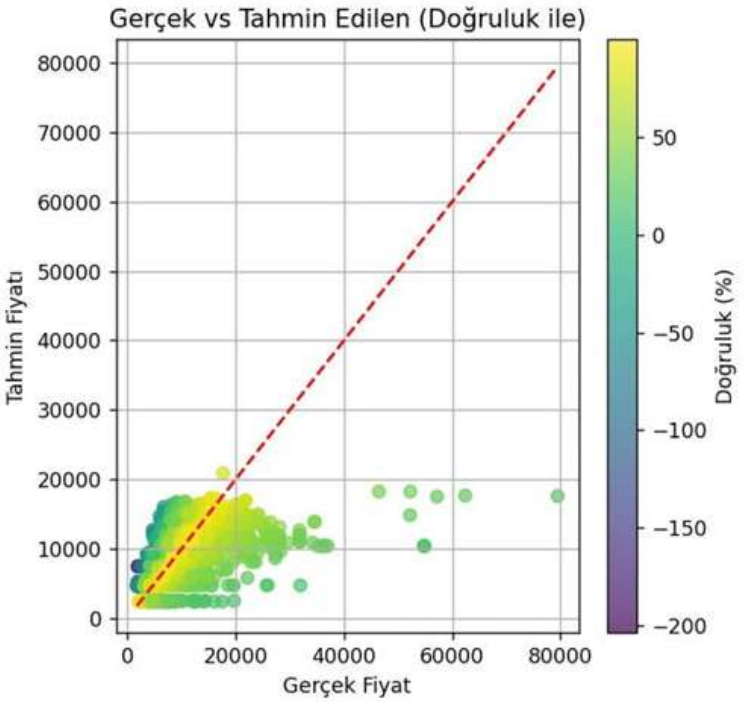
küresel optimuma ulaşma şansını artırır ancak hesaplama maliyeti yükselir. Başlangıç popülasyonu rastgele oluşturulabilir veya sezgisel yöntemlerle desteklenerek daha kaliteli çözümlerle başlamak mümkündür. Bu projede sezgisel yöntemler kullanılarak oluşturulan kromozomlar, tamamen rastgele oluşturulanlara göre daha iyi sonuçlar vermiştir.

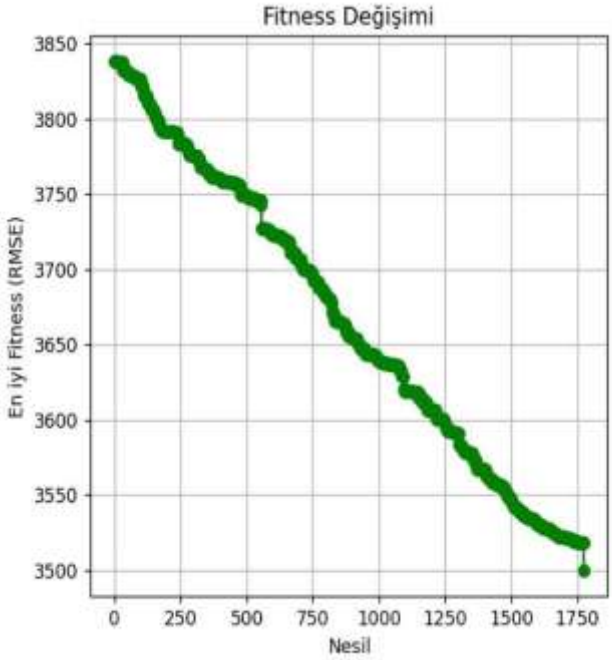
Ebeveyn kromozomların seçilmesinde elit seçim yöntemi tercih edilmiştir; burada en iyi uygunluk değerine sahip birkaç birey ebeveyn olarak seçilir ve böylece çözüme hızlı yakınsama sağlanır. Çaprazlama işlemi tek noktalı olarak gerçekleştirilir; belirlenen noktaya kadar genler bir ebeveynden, geri kalan genler diğer ebeveynden alınarak yeni çocuk kromozomlar oluşturulur. Mutasyon ise popülasyondaki genetik çeşitliliği korumak için uygulanır ve bu projede mutasyon oranı %20 olarak belirlenmiştir. Mutasyon, genellikle rastgele genlerin değiştirilmesi veya permütasyonda genlerin yer değiştirmesi şeklinde olur ve böylece algoritmanın yerel minimumda takılmasının önüne geçilir.

Yeni nesil, ebeveynlerden çaprazlama ve mutasyonla elde edilen çocukların uygunluk değerlerine göre mevcut popülasyondaki bireylerle karşılaştırılması sonucunda oluşturulur. Daha iyi uygunluk değerine sahip çocuklar popülasyona dahil edilir. Bu süreç, belirlenen nesil sayısına ya da durdurma kriterine ulaşılana kadar devam eder. Sonuç olarak, genetik algoritmalar karmaşık, çok boyutlu problemlerde küresel optima ulaşmayı hedefleyen etkili ve esnek metasezgisel yöntemlerdir.

SONUÇ

Modelin tahmin ettiği ve gerçek fiyatlar arasındaki ilişki, iki boyutlu bir saçılım grafiğiyle görselleştirilmiştir. X ekseni gerçek fiyatları, Y ekseni ise model tarafından tahmin edilen fiyatları göstermektedir. Kırmızı kesikli çizgi, tahminlerin ideal doğrulukta olduğu durumu temsil ederken, noktaların renkleri tahmin doğruluğunu yüzde cinsinden ifade etmektedir; sarı tonlar yüksek, mor tonlar ise düşük doğruluk aralıklarını belirtmektedir. Grafik, modelin özellikle düşük ve orta fiyat aralıklarında güçlü performans sergilediğini ve farklı fiyat seviyelerindeki tahmin dağılımını renk ve konum üzerinden bütüncül bir şekilde sunduğunu göstermektedir. Ayrıca, Genetik Algoritma'nın her nesilde elde ettiği en iyi bireyin fitness (RMSE) değerinin değişimi zamanla grafikte izlenmiştir. Bu grafik, algoritmanın ilk 500 nesilde hızlı bir şekilde hata değerini azalttığını, sonraki nesillerde ise daha yatay bir seyirle optimum çözüme yaklaştığını ortaya koymaktadır. Son nesilde yaklaşık RMSE = 3500 seviyelerine ulaşılması, modelin hatayı minimize etme yeteneğini göstermektedir.


Gerçek vs Tahmin Edilen (Doğruluk ile)
Tahmin Fiyatı
Gerçek Fiyat
Doğruluk (%)
0
10000
20000
30000
40000
50000
60000
70000
80000
0
20000
40000
60000
80000
50
0
−50
−100
−150
−200


Fitness Değişimi
En iyi Fitness (RMSE)
Nesil
3500
3550
3600
3650
3700
3750
3800
3850
0
250
500
750
1000
1250
1500
1750

DEEP LEARNING-BASED POWER OUTAGE PREDICTION USING METEOROLOGICAL AND GRID DATA

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ABSTRACT

In modern electricity distribution networks, power outages occur due to various factors such as meteorological events, aging grid infrastructure, and technical deficiencies. These outages lead to significant socioeconomic consequences such as disruption of industrial production, financial losses for businesses, and reduced quality of life for subscribers.

This study presents an advanced forecasting model that uses atmospheric and electrical system data to predict power outages in distribution circuits in Sivas Central District. Considering that power outages can lead to severe economic and social disruptions, the development of proactive forecasting systems has become increasingly critical. The proposed model uses a Long Short-Term Memory (LSTM), a recurrent neural network (RNN) optimized for time series forecasting, to capture complex temporal dependencies in outage patterns. By integrating meteorological variables such as temperature, wind speed, precipitation, and snow depth with power grid operational data, the model improves outage forecasting accuracy.

The dataset extends from 2020 to 2023 for training, while the 2024 data is reserved for testing. The model demonstrates robust performance by achieving a Mean Absolute Error (MAE) of 4.32 and an R^2 score of 0.42 in 24-hour outage forecasts. These metrics demonstrate that the LSTM-based approach can leverage historical trends and environmental factors to predict future outages. Additionally, the study explores the importance of features by finding that extreme weather conditions, particularly high wind speeds and heavy snowfall, significantly impact outage occurrences.

The findings provide practical insight for utility companies to optimize maintenance planning, prioritize resource allocation, and increase grid resilience. By leveraging predictive analytics, utilities can shift to predictable outage management, minimize outage duration, and increase service reliability. Future research directions include integrating real-time data streams and extending the model to regional-scale forecasts.

Keywords: Power outage prediction, LSTM (Long Short-Term Memory), Fault detection in power systems, Machine learning in energy, Atmospheric data in power systems

Giriş

Elektrik kesintileri, modern toplumların karşılaştığı en kritik altyapı sorunlarından biridir. Geleneksel istatistiksel yöntemler, zaman serisi verilerindeki karmaşık desenleri yakalamada yetersiz kalmaktadır (LeCun, Y., Bengio, Y., & Hinton, G., 2015). Uzun Kısa-Vadeli Bellek (LSTM) ağları, zaman serisi tahmin problemlerinde özellikle uzun vadeli alışkanlıkları modelleme yeteneğiyle öne çıkmaktadır (Hochreiter, S., & Schmidhuber, J., 1997). Bu çalışmada, elektrik arızalarının tahmini için LSTM ağlarının performansı detaylı olarak incelenmiştir. Model, 2020-2023 dönemi arıza kayıtları ve hava durumu verileri kullanılarak eğitilmiş, 2024 yılı verileri üzerinde test edilmiştir. Bu çalışma, derin öğrenme tekniklerini kullanarak elektrik kesintilerini öngörmeyi ve şu temel araştırma sorularını yanıtlamayı amaçlamaktadır:

a) Sivas ilindeki meteorolojik parametreler ile şebeke arızaları arasındaki ilişkiler nasıl modellenebilir?

b) LSTM ağları, bu tür kesintilerin tahmininde nasıl bir performans sergiler?

c) Tahmin modelleri kullanılarak operasyonel verimlilik nasıl artırılabilir?

Materyal ve Yöntem

Çalışmada 2020-2024 yılları arasında toplanan günlük elektrik arıza verileri kullanılmıştır. Veri seti günlük arıza sayıları, hava durumu parametreleri (sıcaklık, yağış, rüzgar hızı), şebeke tipi (havai/yeraltı) ve mevsimsel bilgileri içermektedir. Veri ön işleme adımları olarak eksik veriler medyan ile doldurulmuş, Yeo-Johnson dönüşümü uygulanmış 14 günlük zaman pencereleri oluşturulmuş, veriler eğitim (%80) ve test (%20) olarak ayrılmıştır.

Geliştirilen LSTM modeli iki katmandan oluşmaktadır: Birinci LSTM katmanı 64 nöron içermekte, ikinci LSTM katmanı ise 32 nöron içermektedir. Modelde aşırı öğrenmeyi önlemek için %20 oranında dropout katmanı eklenmiştir. Modelin çıktı katmanı tek nöronlu yoğun bir katmandır. Model TensorFlow / Keras kütüphanesi (Géron, A., 2019) kullanılarak Python'da geliştirilmiştir (Brownlee, J., 2018).

Tablo 1. Kullanılan kütüphaneler ve kullanım amaçları.

Kütüphane	Kullanım Amacı
Pandas, NumPy	Veri işleme, temizleme, özellik mühendisliği
Matplotlib, Seaborn	Veri görselleştirme, performans analizi
Scikit-learn	Veri ölçeklendirme, özellik seçimi, model değerlendirme
TensorFlow/Keras	Derin öğrenme modeli (LSTM)
Scipy (stats)	Veri normalizasyonu (Yeo-Johnson dönüşümü)
TimeSeriesSplit	Zaman serisi çapraz doğrulama
Mutual Info Regression	Özellik önem analizi

Modelin performansı RMSE, MAE, SMAPE ve R^2 metrikleri kullanılarak değerlendirilmiştir.

Ortalama Mutlak Hata (MAE), yön olmaksızın hataların ortalama mutlak büyüklüğünü hesaplayan yaygın bir ölçüdür. MAE aşağıdaki şekilde uygulanır:

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |y_i - \hat{y}_i| \quad (1)$$

Burada y_i gerçek kesinti sayısı, $\hat{y}_i$ tahmin edilen kesinti sayısı ve n gözlem sayısıdır (Chai, T., Draxler, R. R., 2014). MAE sezgisel bir hata büyüklüğünü yakalar ve bu nedenle model doğruluğu açıklaması için tercih edilen bir ölçüdür.

Ortalama Karesel Hata (RMSE), kareleme işlemi nedeniyle daha büyük hataları daha küçük olanlardan daha fazla baskılayan başka bir performans ölçüsüdür. Şu şekilde uygulanır:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (y_i - \hat{y}_i)^2} \quad (2)$$

RMSE, gerçek değerlerden daha büyük sapmaların daha büyük etkilere sahip olduğu durumlarda, örneğin son derece yüksek tahmin hatalarının operasyonel verimsizliklere yol açtığı elektrik kesintisi tahminlerinde özellikle yararlıdır (Botchkarev, A., 2019).

Ortalama Mutlak Yüzde Hatası (MAPE), hatayı gerçek değerin yüzdesi olarak temsil eder ve göreceli bir tahmin performansı sağlar ve şu şekilde uygulanır:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} \left|\frac{y_i - \hat{y}_i}{y_i}\right| x100\% \quad (3)$$

Bu metrik, özellikle değişen ölçeklere sahip veri kümeleri arasında model karşılaştırması için kullanışlıdır. Gerçek değerler sıfıra yaklaştığında sınırlıdır, çünkü küçük sayılara bölme yapay olarak yüksek hatalara yol açabilir (De Myttenaere, A., Golden, B., Le Grand, B., Rossi, F., 2016).

R kare (R^2) metriği, bağımlı değişkendeki varyansın model tarafından açıklanan oranını belirler. Şu şekilde hesaplanır:

$$R^2 = 1 - \frac{\frac{1}{n}\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\frac{1}{n}\sum_{i=1}^{n} (y_i - \bar{y}_i)^2} \quad (4)$$

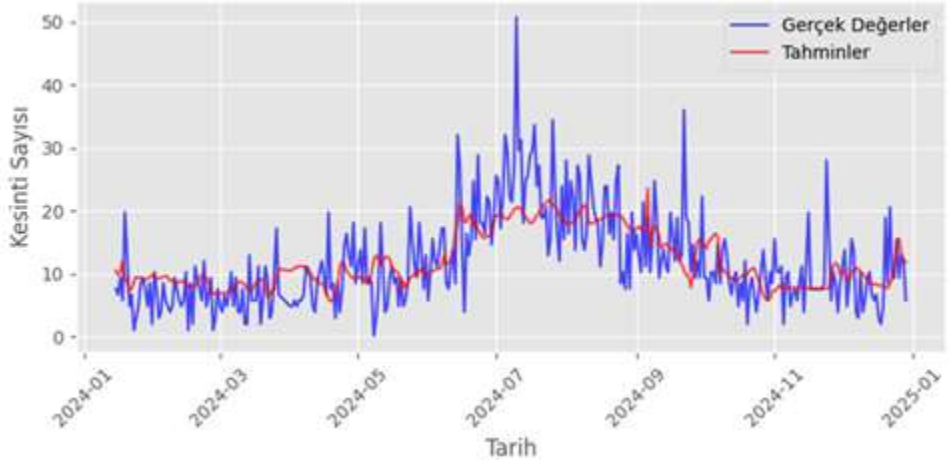
formülde $\bar{y}$ gerçek değerlerin ortalamasını temsil eder (Alexander, D. L., Tropsha, A., Winkler, D. A., 2015). 1'e yakın bir R^2, iyi tahmin yeteneğini gösterirken, 0'a yakın değerler modelin iyi bir tahminleme yapamadığını gösterir.

Bulgular ve Tartışma

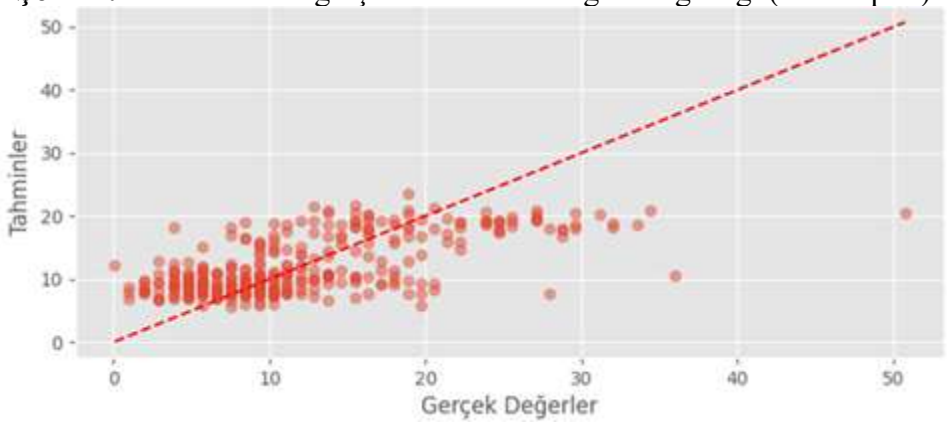
LSTM modeli test verisi üzerinde RMSE: 5.70, MAE: 4.32 ve SMAPE: %39.48 değerleriyle başarılı sonuçlar vermiştir. R^2 değeri 0.42 olarak hesaplanmıştır. Bu sonuçlar, modelin elektrik arızalarını tahmin etmede etkili olduğunu göstermektedir. LSTM ağlarının zaman serisi verilerindeki başarısı, uzun vadeli alışkanlıkları yakalama yeteneğiyle açıklanabilir (Hochreiter, S., & Schmidhuber, J., 1997).

Hata analizleri, yaz mevsiminde ortalama hataların 5.67 ile en yüksek seviyede olduğunu göstermiştir. Bu durum, yaz aylarındaki normal dışı hava olaylarının modelin tahmin kapasitesini zorladığını düşündürmektedir. Havai hatlarda arıza tahmin hataları, yeraltı hatlarına göre %25 daha fazla çıkmıştır. Bu sonuç, havai hatların hava koşullarından daha fazla etkilenmesiyle açıklanabilir. Tahminlerin %34.5'i "İyi" kategorisinde (hata oranı >%10 ve <%30) sınıflandırılırken, %12.7'si "Çok Kötü" kategorisinde (hata oranı >%100) yer almıştır. En büyük hatalar, ani ve şiddetli hava olaylarının yaşandığı günlerde gözlemlenmiştir.

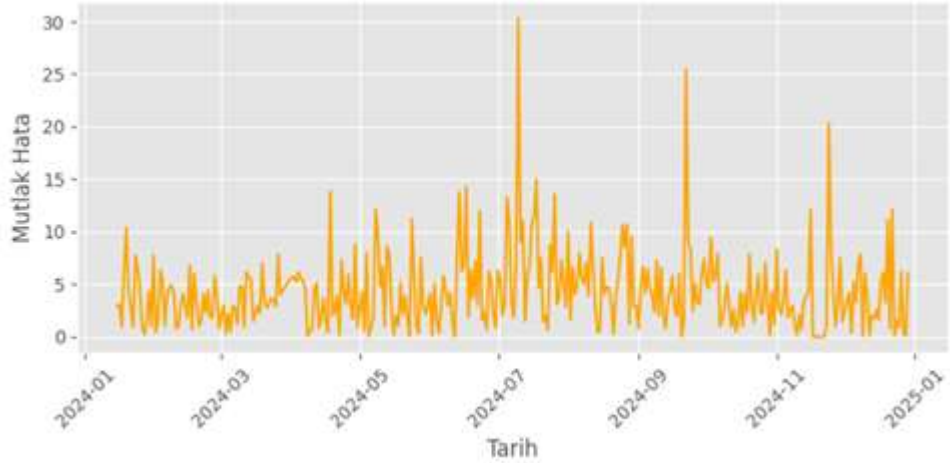
Şekil 1. LSTM modeli gerçek ve Tahmin değerleri grafiği (çizgi)



Şekil 2. LSTM modeli gerçek ve Tahmin değerleri grafiği (scatter plot)



Şekil 3. LSTM modeli hatanın zaman içinde değişim grafiği



Sonuç ve Öneriler

Bu çalışma, elektrik kesintilerinin meteorolojik ve şebeke faktörleriyle tahmin edilebileceğini göstermiştir. Mevsimsel faktörlerin, özellikle yaz aylarında model performansını önemli ölçüde etkilediği tespit edilmiştir. Havai hatların yeraltı hatlarına göre daha yüksek arıza oranları gösterdiği ve bu hatlardaki tahmin hatalarının daha fazla olduğu belirlenmiştir.

Gelecek çalışmalar için şu öneriler sunulabilir:

a) Gerçek zamanlı veri akışı sağlayan IoT sistemlerinin entegrasyonu,

b) Ekstrem hava olayları için özel modüller geliştirilmesi,

c) Daha uzun zaman aralıklarını kapsayan veri setlerinin kullanılması.

Bu iyileştirmeler, model performansını artırabilir ve daha güvenilir tahminler sağlayabilir.

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A WEB-BASED MACHINE LEARNING APPLICATION FOR SOLAR POWER GENERATION PREDICTION

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ABSTRACT

Solar energy is one of the most important components in the global renewable energy landscape due to its sustainability and potential to reduce the impact of fossil fuels. Among the many renewable energy sources available, solar energy occupies an important place due to its advantages such as being clean, accessible, low environmental impact, easy to maintain and install. Solar panels can be easily deployed in many environments, from building rooftops to solar farms. Their high accessibility and benefits have increased their use in both rural and urban areas. The rapid increase in the number of solar installations and the growing global demand for electricity have made the efficiency and reliability of solar power generation important research topics. To address the challenges arising from the variability in solar power generation, this study introduces a web-based application tool that provides a comparative analysis of various machine learning algorithms for predicting real-world solar power generation. The algorithms used in the study are Linear Regression, Gradient Boosting, Random Forest, Decision Tree, K-Nearest Neighbour, Support Vector and XgBoost

Regressors. The developed web application tool allows users to upload their data set and select one of the above-mentioned machine learning algorithms to perform prediction. The web application includes prediction results, data statistics, exploratory data analysis, and presentation of a small sample of the data set. The application was developed by using the Flask framework, which provides a highly flexible and user-friendly interface. This forecasting tool can be used effectively in optimizing the planning and management of solar energy systems.

Keywords: Machine Learning, Data Analysis, Solar Power Plant, Web Application.

GÜNEŞ ENERJİSİ ÜRETİMİ TAHMİNİ İÇİN WEB TABANLI MAKİNE ÖĞRENİMİ UYGULAMASI

ÖZET

Güneş enerjisi, sürdürülebilirliği ve fosil yakıtların etkisini azaltma potansiyeli nedeniyle küresel yenilenebilir enerji kaynaklarının en önemli bileşenlerinden biridir. Mevcut birçok yenilenebilir enerji kaynağı arasında güneş enerjisi, temiz, erişilebilir, çevreye etkisi düşük, bakımı ve kurulumu kolay gibi avantajları nedeniyle önemli bir yer tutmaktadır. Güneş panelleri, bina çatılarından güneş enerjisi santrallerine kadar birçok ortamda kolayca kullanılabilir. Kolay erişilebilirliği ve faydaları hem kırsal hem de kentsel alanlarda kullanımını artırmıştır. Güneş enerjisi tesislerinin sayısındaki hızlı artış ve küresel elektrik talebinin artması, güneş enerjisi üretiminin verimliliği ve güvenilirliğini önemli araştırma konuları haline getirmiştir. Güneş enerjisi üretimindeki değişkenlikten kaynaklanan zorlukları ele almak için, bu çalışma, gerçek dünyadaki güneş enerjisi üretimini tahmin etmek için çeşitli makine öğrenimi algoritmalarının karşılaştırmalı analizini sağlayan web tabanlı bir uygulama aracı sunmaktadır. Çalışmada; Linear Regression, Gradient Boosting, Random Forest, Decision Tree, K-Nearest Neighbor, Support Vector Machine, XGBoost algoritmaları kullanılmıştır. Geliştirilen web uygulama aracı, kullanıcıların veri setlerini yüklemelerine ve tahmin yapmak için yukarıda belirtilen makine öğrenimi algoritmalarından birini seçmelerine olanak tanır. Web uygulaması, tahmin sonuçlarını, veri istatistiklerini, keşifsel veri analizini ve veri kümesinin küçük bir örneğinin sunumunu içerir. Uygulama, son derece esnek ve kullanıcı dostu bir arayüz sağlayan Flask kütüphanesini kullanarak geliştirilmiştir. Bu tahmin aracı, güneş enerjisi sistemlerinin planlaması ve yönetiminin optimizasyonunda etkili bir şekilde kullanılabilir.

Anahtar Kelimeler: Makine Öğrenimi, Veri Analizi, Güneş Enerjisi Santrali, Web Uygulaması.

Giriş

Yenilenebilir bir enerji kaynağı olan güneş enerjisi; temiz olması, erişilebilirliği, düşük çevresel etkisi, kolay kurulum ve bakım gibi avantajları sayesinde önemli bir yer almaktadır. Gelişen teknoloji ile birlikte üretim verimliliği de artmaktadır. Fakat güneş enerjisi üretimi sıcaklık, ışınım, rüzgâr ve nem gibi iklim verilerinden etkilenmektedir. Bu iklim verilerinin doğru analiz edilmesi, güneş enerjisi üretiminin daha sağlıklı tahmin edilmesini ve enerji yönetiminin daha etkin planlanmasını sağlamaktadır. Güneş enerjisi üretimini tahmin etmeye yönelik çalışmalar, son yıllarda özellikle yapay zekâ gibi veri yaklaşımları ile hız kazanmıştır. Bu yöntemler, geçmiş üretim verileri ve iklim verileri kullanılarak gelecekteki üretim miktarlarını büyük bir doğrulukla öngörebilmeyi sağlamaktadır. Literatürdeki çalışmalar, makine öğrenmesi ve derin öğrenme gibi yapılardan faydalanılarak üretim tahminlemenin doğru ve güvenilir olarak yapılabileceğini göstermiştir.

Bu çalışmada, Kahramanmaraş ilinde bulunan İbrahim Taşyurdu GES'in 2019-2022 yılları arasındaki üretim verileri kullanılarak üretim tahminlemesi yapan ve web ara yüzüne sahip bir uygulama gerçekleştirilmiştir. Linear Regression, Gradient Boosting, Random Forest, Decision Tree, K-Nearest Neighbor, Support Vector Machine, XGBoost algoritmaları kullanılarak tahmin çalışmaları daha hızlı ve güvenilir hâle gelmiştir. Çalışmada kullanılan ara yüz ise kullanıcı dostu, kolay entegrasyon ve mobil uyumluluğu gibi özelliklerinden dolayı Flask kütüphanesi ile geliştirilmiştir.

Literatür Taraması

Bu bölümde güneş enerjisi üretimi tahminlemede literatürde yapılan çeşitli çalışmalar gözden geçirilmiş ve özetlenmiştir.

Çetin ve Işık tarafından yapılan çalışmada, Türkiye'nin farklı şehirlerinde bulunan güneş enerji santrallerine ait aylık üretim verileri kullanılarak LSTM tabanlı bir tahmin modeli geliştirilmiştir. Modelde, güneşlenme süresi, panel tipi ve inverter özellikleri gibi faktörler dikkate alınmıştır. Dokuz farklı şehirden elde edilen toplam 708 veri ile eğitilen modelin hata oranlarının %1 ile %17 arasında değiştiği gözlemlenmiştir. Özellikle yaz mevsiminde daha düşük hata oranları elde edilmiştir. Bu bulgular, LSTM gibi derin öğrenme modellerinin güneş enerjisi santrallerinin aylık üretim tahmininde etkili ve güvenilir bir yöntem olduğunu göstermektedir (Çetin & Isık, 2022).

Nkuriyingoma ve Selçuklu tarafından gerçekleştirilen çalışmada ise kısa ve orta vadeli güneş enerjisi üretim tahmini konusu ele alınmış ve bu kapsamda yeni bir yapay sinir ağı modeli önerilmiştir. Modelde, küresel güneş radyasyonu, sıcaklık, bağıl nem, rüzgâr ve yağış gibi çeşitli iklimsel değişkenlerin etkisi analiz edilmiştir. Çalışmada Türkiye'ye ait belirli bir bölgenin geçmiş iklimsel verileri kullanılmıştır. Eksik verilerin uygun yöntemlerle tamamlanmasının model performansını artırdığı vurgulanmıştır. Modelin doğruluğu, hata analizleri ve başarı oranları üzerinden değerlendirilmiş; en uygun değişken kombinasyonlarıyla yüksek doğruluk seviyelerine ulaşılmıştır. Bu kapsamda, yeni bir modelinin güneş enerjisi üretim tahmini açısından etkili bir yaklaşım sunduğu ortaya konmuştur (Nkurıyıngoma & Selçuklu, 2021).

Uz ve arkadaşları, Bakırçay Üniversitesi kampüsünde bulunan 400 kW gücündeki güneş enerjisi santralinin aylık elektrik üretimini, İzmir iline ait iklimsel veriler kullanarak Yapay Sinir Ağı (YSA) ile tahmin etmeyi amaçlamıştır. Çalışmada girdi değişkenleri olarak aylık ortalama güneşlenme süresi, ortam sıcaklığı, bulutlu gün sayısı ve ortalama güneş ışınımı kullanılmış; çıktı olarak ise santralden elde edilen aylık elektrik üretim değerleri alınmıştır. Model performansı, %95,33 doğruluk oranı ve %4,67 hata oranı ile değerlendirilmiştir. Elde

edilen bulgular, iklimsel veriler kullanılarak geliştirilen YSA modelleri ile güneş enerjisi üretiminin yüksek doğrulukla tahmin edilebileceğini göstermektedir (Uz, Özdemir, & Özmen, 2022).

Altıparmak ve Aksu tarafından yürütülen bir diğer çalışmada da Türkiye'nin kurulu elektrik kapasitesi üzerine tahminler yapılmış ve GRU, CNN ve LSTM modelleri karşılaştırılmıştır. Bu çalışmada da test sürecinde GRU modeli, en düşük RMSE değerini elde ederek en başarılı model olarak öne çıkmıştır. Eğitim sürecinde yüksek başarı elde eden CNN modeli, test aşamasında ise GRU modeline kıyasla daha yüksek hata değerleri üretmiştir. Tüm modeller, 2030 yılına kadar elektrik kapasitesinde artış görüleceği yönünde tahminleme yapmışlardır (Altıparmak & Aksu, 2024).

Yavuz ve Botsalı, Konya bölgesindeki güneş enerjisi santrallerine ait elektrik üretim miktarlarını hava durumu verileri kullanarak tahmin etmeyi amaçlamıştır. Çalışmada kullanılan YSA modelleri; güneş ışınımı, nem, saat ve ay gibi meteorolojik parametreleri girdi olarak almıştır. Veri seti, 24 güneş enerjisi santraline ait bir yıllık saatlik elektrik üretim verileri ile yerel hava durumu verilerinden oluşmaktadır. Modellerin performansı ortalama hata oranı ile değerlendirilmiş ve en başarılı modelin %4,94 hata oranı ile oldukça yüksek doğrulukla tahmin yaptığı belirlenmiştir. Elde edilen bulgular, hava durumu verilerinin kullanılmasıyla güneş enerjisi üretiminin etkin biçimde tahmin edilebileceğini göstermektedir (Yavuz & Botsalı, 2022).

Materyal ve Metot

Bu bölümde, kullanılan veri seti ve makine öğrenmesi algoritmaları özetlenmiştir. Deneysel çalışmalarda kullanılan metrikler hakkında bilgi verilmiştir.

Veri Seti

Bu çalışmada Kahramanmaraş ilinde bulunan İbrahim Taşyurdu GES'e ait üretim verisi kullanılmıştır. Kahramanmaraş ili, Pazarcık ilçesi, Memişkahya Mahallesi 906 ada, 3 parsel içerisinde işletme çatısı üzerinde bulunan 469,2 kWe kurulu gücündeki (İbrahim Taşyurdu GES) güneş enerjisi santrali baz alınmıştır.

Elde edilen veri seti 2 sütun ve 35055 satırdan oluşmakta olup ilk sütunu üretim tarihi ikinci sütun ise üretilen elektrik miktarını göstermektedir. 01.01.2019 tarihinden başlayarak 31.12.222 tarihine kadar devam eden 4 yıllık günlük üretim verileri gerçek GES verisi olması sebebiyle yapılan çalışmanın önemini daha çok ortaya koymaktadır. Şekil 1'de veri setindeki 1 günlük üretim örneği sunulmuştur.



Şekil 4. Kullanılan Üretim Verisi Örneği

Makine Öğrenmesi Modelleri

Makine öğrenmesi algoritmaları ile geçmiş verilerden öğrenilenlere dayanarak ve bu verilerden elde edilenleri yeni verilere uygulayarak tahminlerin sağlanması amaçlanmıştır. Bu çalışmada makine öğrenmesinde kullanılan yedi algoritma aşağıda açıklanmıştır.

Linear Regression (LR): Bu yöntem, bağımlı değişken ve bağımsız değişken arasında neden-sonuç ilişkisi ile bağımlı değişkenin bağımsız değişkenlerle bağıntı kurmasını sağlayarak tahmin yapmayı amaçlamaktadır. (Korkmaz, Dogan, & Kırmacı, 2022).

Gradient Boosting (GB): zayıf öğrenicileri güçlü öğrenicilere çevirme mantığı ile çalışan bir yöntemdir. Zayıf öğreniciler genellikle karar ağaçlarıdır. Bu algoritmada önceki ağacın hataları en aza indirgenerek bir sonraki ağaç oluşturulur (Yeşilyurt & Dalkılıç, 2021).

Random Forest (RF): topluluk öğrenme yöntemine dayanan ve birden fazla karar ağacını birleştirerek çalışan güçlü bir makine öğrenmesi algoritmasıdır. Aşırı uyumu azaltması ve dengesiz verilerle etkili şekilde başa çıkabilmesi sayesinde hem sınıflandırma hem de regresyon görevlerinde sıkça kullanılır (Doğanlı, 2025).

Decision Tree (DT): regresyon ağacını ve sınıflama ağacını bir arada tutan bir algoritmaya sahiptir. Bu algoritma, veri setini alt örneklemlere ayırmaktadır. Düğümler ve dallardan oluşan karar ağacı diyagramlarını görsel olarak sunabilmektedir (Özkan, Parim, & Çene, 2023).

XGBoost (XGB): Gradient boosting algoritmasının geliştirilmesiyle oluşturulmuştur. Yüksek tahmin gücü, aşırı öğrenmenin önüne geçebilmesi, hızlı olması gibi sebeplerden dolayı avantajlı bir yöntem sunmaktadır (Yeşilyurt & Dalkılıç, 2021).

K-Nearest Neighbor (KNN): Bu algoritma, “bir örneğin sonucu kendisine en yakın komşu örneklerin sonucu ile aynı olur” fikrini esas alarak regresyon problemleri için kullanılan bir makine öğrenmesi algoritmasıdır (Altunkaynak, Başakın, & Kartal, 2020).

Support Vector Regression (SVR): SVR regresyon algoritması, kernel tabanlı sınıflandırma algoritmasıdır. SVRler, veri noktalarını sınıflandırmak ve tahmin etmek için düzlemde bir çizgi ile eğri bulmaktadır (Akı & Akal, 2023).

Metrikler

Model değerlendirmesinde kullanılan MAE (Bulut & Milli, 2016), MSE, RSME (Diker & Aslan, 2022) ve R^2 (Ertürk, Kara, Akkuş, & Genç, 2023) gibi hata metrikleri aşağıda açıklanmıştır. Denklem 1-4 arasındaki formüllerde, y_i gerçek değeri, $\widetilde{y_i}$ tahmin edilen değeri, $\overline{y_i}$ gerçek değerlerin ortalamasını ve n gözlem sayısını ifade etmektedir.

Mean Absolute Error (MAE): hataların mutlak değerlerinin ortalaması ile bulunmaktadır. Denklem 1'de formülü verilmiştir.

$$MAE = \frac{1}{n}\sum_{i=1}^{n} | y_i - \widetilde{y_i} | \quad (1)$$

Mean Squared Error (MSE): tahmin hatalarının karelerinin toplanarak elde edilen değerin n (gözlem sayısı) sayısına bölünmesiyle bulunmaktadır. Denklem 2'de formülü verilmiştir.

$$MSE = \frac{1}{n}\sum_{i=1}^{n} (y_i - \widetilde{y_i})^2 \quad (2)$$

Root Mean Square Error (RMSE): tahmin hatalarının karelerinin toplanarak değerin n (gözlem sayısı) sayısına bölünmesi ve çıkan sonucun karekökünün alınmasıyla bulunmaktadır. Denklem 3'de formülü verilmiştir.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \widetilde{y_i})^2}{n}} \quad (3)$$

R-Squared (R^2): Modellerin performansını tahmin etmek için kullanılmaktadır. R^2 değeri 0 ile 1 arasında değer almaktadır. Değer 1'e yakın olması modelin doğruluğunun yüksek olduğu anlamına gelmektedir. Denklem 4'de ilgili formül verilmiştir.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \widetilde{y_i})^2}{\sum_{i=1}^{n}(y_i - \overline{y_i})^2} \quad (4)$$

Bulgular ve Tartışma

Bu bölümde çalışma kapsamında elde edilen sonuçlar sunulmuş ve değerlendirmelerde bulunulmuştur.

Makine Öğrenmesi Algoritmalarının Karşılaştırılması

Bu çalışma kapsamında seçilen makine öğrenmesi modellerinin mevcut veri seti üzerindeki performanslarının karşılaştırılması aşağıdaki Tablo 1'te verilmiştir. Bu kapsamda LR, GB, RF, DT, KNN, SVR, XGB makine öğrenmesi algoritmaları ve MAE, RMSE, MSE, R^2 metrikleri ele alınmıştır. Elde edilen deneysel sonuçlara göre en yüksek R^2 sonucu GB algoritmasında gözlemlenmiştir.



Şekil 2. Arayüz Tasarımı

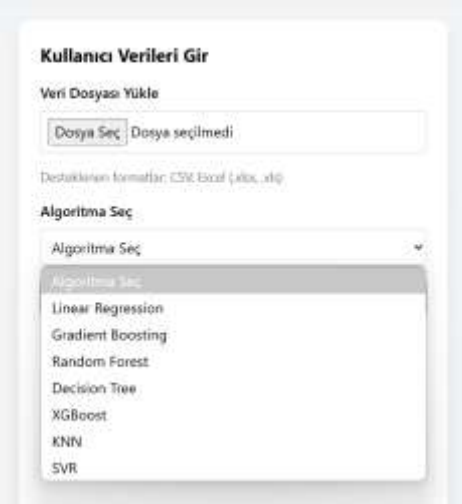
Tablo 1. Makine Öğrenmesi Modellerinin Performans Karşılaştırması

Algoritmalar	MAE	RMSE	MSE	R^2
GB	13.55	26.30	691.90	0.9583
XGB	15.05	26.80	718.38	0.9567
SVR	16.49	26.92	724.53	0.9563
KNN	13.34	28.32	802.19	0.9516
RF	13.83	28.59	817.27	0.9507
LR	20.95	32.31	1043.88	0.9370
DT	15.16	33.03	1090.78	0.9342

Geliştirilen Makine Öğrenmesi Web Uygulaması

Bu çalışmada, güneş enerjisi üretiminin tahminlemesi için geliştirilmiş web tabanlı bir makine öğrenmesi uygulaması sunulmaktadır. Şekil 2'de ara yüzü gösterilen uygulama, Python programlama dili ve Flask web çerçevesi kullanılarak geliştirilmiştir. Sistem, yedi farklı makine öğrenmesi algoritmasını içermektedir. Şekil 3'de gösterildiği üzere uygulama, veri setlerinin CSV veya Excel (.xlsx, .xls) formatlarında yüklenmesine olanak sağlamakta ve kullanıcıların tercih ettikleri makine öğrenmesi algoritmasını seçerek tahminleme işlemini gerçekleştirmelerine imkân tanımaktadır.

Sistemin ilk aşamasında, yüklenen veri setinin temel istatistiksel analizleri gerçekleştirilmekte ve kullanıcıya sunulmaktadır. Bu süreçte veri setinin minimum, maksimum ve ortalama



Şekil 3. Veri ve Algoritma Seçimi

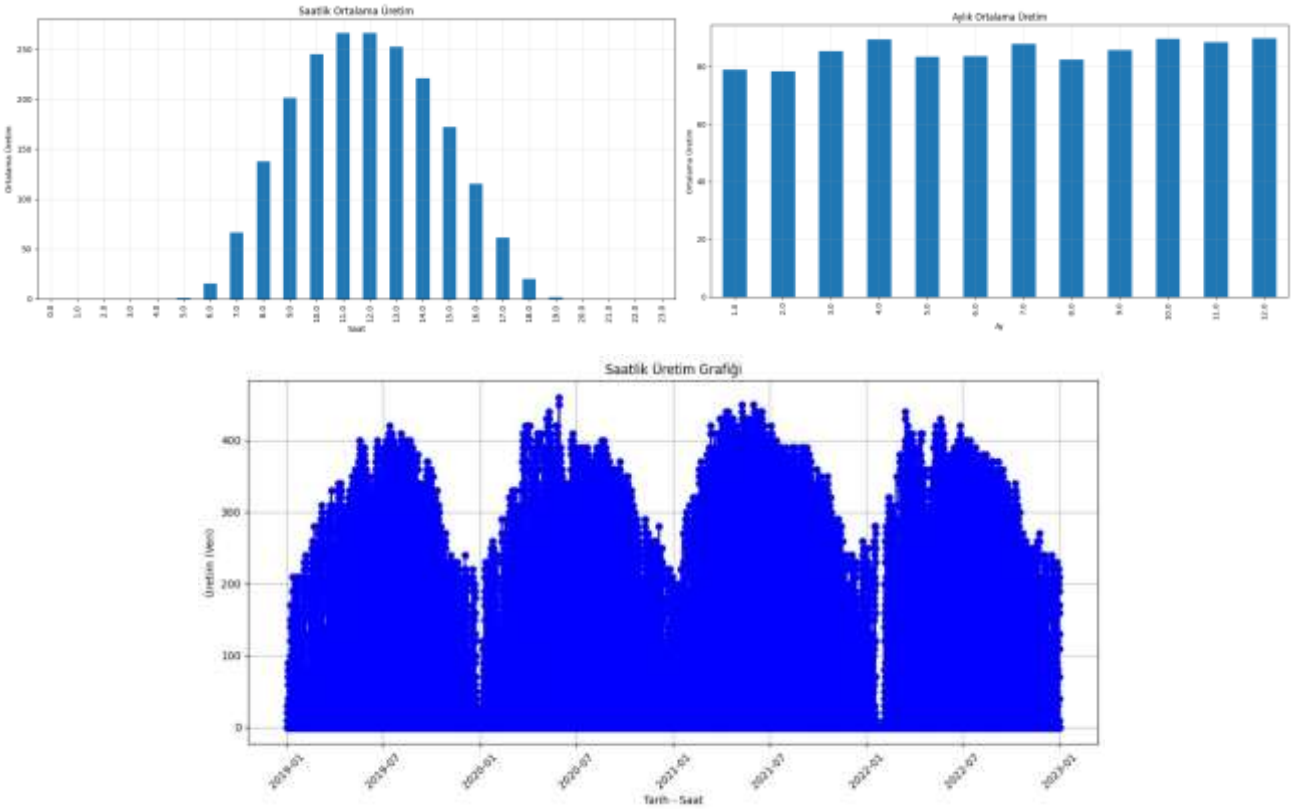
değerleri hesaplanarak veri seti hakkında bilgi verilmektedir. Sistemin ikinci aşamasında, keşifsel veri analizi (EDA) gerçekleştirilmektedir. Geliştirilen sistemde, veri analizi süreci öncelikle temel istatistiksel göstergelerin incelenmesiyle başlamaktadır. Aşağıda Tablo 2'de veri setine ilişkin temel istatistiksel özetleme sunulmuştur.

Tablo 2. Temel İstatistikler

İstatistik	Üretim (Veri)
Count	35055.00
Mean	85.10
Std	123.88
Min	0.00
25%	0.00
50%	0.00
75%	160.00
Max	460.00

Şekil 4'te gösterildiği gibi güneş enerjisi üretiminin saatlik ve aylık ortalamaları hesaplanmakta ve çubuk grafikleri ile görselleştirilmektedir. Saatlik analiz, güneş enerjisi üretiminin gün içindeki değişimini gösterirken, aylık analiz mevsimsel değişimleri ortaya çıkarmaktadır. Bu analizler, güneş enerjisi üretimindeki mevsimsel etkileri anlama konusunda önemli bilgiler sağlamaktadır. Özellikle saatlik ortalama üretim grafiği, güneş ışınımının gün içindeki değişimini ve üretim saatlerini net bir şekilde göstermektedir.

Ardından, güneş enerjisi üretim verilerinin dağılımını anlamak için Şekil 5'de gösterildiği gibi üretim-zaman grafiği oluşturulmaktadır.



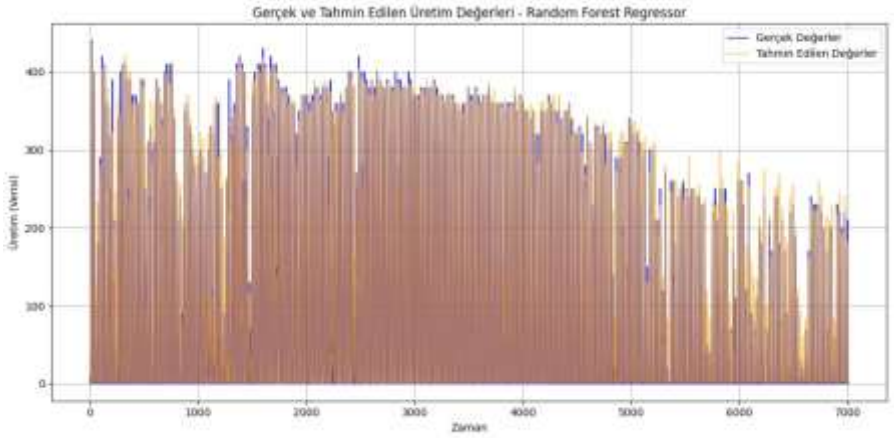
Şekil 5. Üretim-Zaman Grafiği

Şekil 6'da gösterildiği üzere, sistemin en alt bölümünde, kullanıcının veri setini doğrudan inceleyebilmesi için tablo içinde veri setinin ilk 100 satırı sunulmaktadır. Tabloda her bir satır sıralanmış olarak tarih ve üretim değerlerini içermektedir. Ayrıca tablonun üst kısmında veri setinin toplam satır sayısı, sütun sayısı ve dosya adı gibi özet bilgiler de yer almaktadır.



Şekil 6. Üretim-Zaman Grafiği

Geliştirilen sistemin sonuç bölümünde, seçilen makine öğrenmesi algoritmasının performans değerlendirmesi detaylı bir şekilde sunulmaktadır. Her bir model için MAE, MSE, RMSE ve R^2 performans metriği hesaplanmakta ve kullanıcıya gösterilmektedir. Ayrıca sistem bir karşılaştırma grafiği sunmaktadır. Bu grafikte, gerçek üretim değerleri ve modelin tahmin ettiği değerler zaman serisi boyunca görselleştirilmektedir. Grafik üzerinde mavi çizgi gerçek değerleri, turuncu çizgi ise tahmin edilen değerleri temsil etmektedir. Aşağıdaki Şekil 7'de örnek karşılaştırma grafiği verilmiştir.



Şekil 7. Gerçek ve Tahmin Edilen Üretim Değerlerinin Zaman Serisi Analizi

Sonuç ve Öneriler

Geliştirilen web tabanlı güneş enerjisi tahminleme sisteminde, yedi farklı makine öğrenmesi algoritması başarıyla uygulanmıştır. Gerçek saha koşullarından elde edilen veri seti üzerinde analizler ve testler yapılmıştır. Bu çalışmada farklı makine öğrenimi algoritmalarının regresyon performansları karşılaştırılmış ve GB, en düşük mutlak hata değeri olan 13.55 ve en yüksek determinasyon katsayısı olan 0.9583 ile en başarılı model olmuştur. Bunu, 0.9567 doğruluk oranıyla XGB ve 0.9563 doğruluk oranıyla SVR algoritmaları izlemiştir. Ayrıca KNN algoritması da 13.34 mutlak hata ve 0.9516 doğruluk oranı ile başarılı sonuçlar üretmiştir. Öte yandan RF ve LR modelleri daha yüksek hata değerleriyle daha sınırlı doğruluk sağlamıştır. DT ise 0.9342 doğruluk oranı ile kabul edilebilir bir performans sunmasına rağmen hata oranlarının diğer modellere göre daha yüksek olduğu gözlemlenmiştir. Doğruluk oranlarının geliştirilmesi için hava durumu verilerinin de eklenmesi gelecek çalışması olarak düşünülmektedir. Bu iyileştirmeler, tahmin doğruluğunu artırarak güneş enerjisi santrallerinin daha verimli yönetilmesine katkı sağlayacaktır.

Teşekkür ve Bilgi Notu

Bu çalışma kapsamında üretim verilerini paylaşarak çalışmaya katkı sağlayan Kahramanmaraş ilinde bulunan İbrahim Taşyurdu Güneş Enerji Santrali'ne teşekkür ederiz. Sağlanan veriler, analiz ve modelleme süreçlerinde önemli katkı sağlamıştır.

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DETECTION OF RAMP-DOWN EVENTS IN SOLAR POWER GENERATION DATA

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ABSTRACT

Solar energy is an environmentally friendly, renewable, and sustainable energy source, and therefore it holds great importance in modern energy systems. Cost-effectiveness and efficiency have been significantly increased its popularity. Developments in solar panel technologies have also increased the need to reduce carbon emissions, and the growing global awareness of climate change has accelerated the adaptation of solar energy. However, effective and reliable solar energy systems are often affected by unpredictable factors and various dynamics. Daily and seasonal weather changes, cloud cover, atmospheric particles, and dust accumulation conditions lead to various sudden changes in energy generation. Especially, sudden and sharp drops in solar energy generation disrupt the balance between energy supply and demand. This carries a significant risk of affecting the stability of the grid and the overall reliability in renewable energy infrastructures. These unexpected interruptions result from combinations of various factors, both technical and environmental. For example, sudden climate changes such as extreme cloud movements or thunderstorms can reduce the solar irradiance within minutes.

Similarly, system-level errors such as surface contamination on panels, shadows from nearby objects, or inverter failures can cause energy generation anomalies. The detection of such events contributes to the development of an effective control and management strategy. The main purpose of this study is to detect sudden drops in solar energy production using statistical and deep learning-based approaches. A comprehensive analysis has been carried out using photovoltaic system data collected from solar power plant. Detection of outlier data instances have been carried out with various models to detect potential system anomalies. The promising results obtained show that these methods can detect critical changes in energy outputs. Finally, the findings reveal significant contributions to the development of early warning systems, improvement of grid stability, and enhancement of the reliability of the solar energy infrastructure.

Keywords: Solar energy, Ramp-down events, Anomaly detection, Deep learning.

GÜNEŞ ENERJİSİ ÜRETİM VERİLERİNDE ANİ DÜŞÜŞ OLAYLARININ TESPİTİ

ÖZET

Güneş enerjisi, çevre dostu, yenilenebilir ve sürdürülebilir bir enerji kaynağı olduğu için modern enerji sistemlerinde büyük öneme sahiptir. Maliyet etkinliği ve verimliliği, popülerliğini önemli ölçüde artırmıştır. Güneş paneli teknolojilerindeki gelişmeler de karbon emisyonlarının azaltılması ihtiyacını artırmış ve iklim değişikliğine ilişkin küresel farkındalığın artması, güneş enerjisinin benimsenmesini hızlandırmıştır. Ancak, etkili ve güvenilir güneş enerjisi sistemleri genellikle öngörülemeyen faktörlerden ve çeşitli dinamiklerden etkilenmektedir. Günlük ve mevsimsel hava değişiklikleri, bulut örtüsü, atmosferik partiküller ve toz birikimi gibi durumlar, enerji üretiminde çeşitli ani değişikliklere yol açmaktadır. Özellikle, güneş enerjisi üretimindeki ani ve keskin düşüşler, enerji arzı ve talebi arasındaki dengeyi bozmaktadır. Bu durum, şebekenin istikrarını ve yenilenebilir enerji altyapılarının genel güvenilirliğini önemli ölçüde etkileme riski taşımaktadır. Beklenmedik kesintiler hem teknik hem de çevresel çeşitli faktörlerin birleşiminden kaynaklanmaktadır. Örneğin, aşırı bulut hareketleri veya fırtınalar gibi ani iklim değişiklikleri, güneş ışınımını dakikalar içinde azaltabilir. Benzer şekilde, panellerin yüzeyindeki kirlenme, yakındaki nesnelerin gölgeleri veya invertör arızaları gibi sistem düzeyindeki hatalar da enerji üretiminde anormalliklere neden olabilir. Bu tür olayların tespiti, etkili bir kontrol ve yönetim stratejisinin geliştirilmesine katkıda bulunur. Bu çalışmanın temel amacı, istatistiksel ve derin öğrenme tabanlı yaklaşımlar kullanarak güneş enerjisi üretimindeki ani düşüşleri tespit etmektir. Güneş enerjisi santralinden toplanan fotovoltaik sistem verileri kullanılarak kapsamlı bir analiz gerçekleştirilmiştir. Potansiyel sistem anormalliklerini tespit etmek için çeşitli modeller kullanılarak aykırı veri örneklerinin tespiti yapılmıştır. Elde edilen umut verici sonuçlar, bu yöntemlerin enerji çıkışlarındaki kritik değişiklikleri tespit edebildiğini göstermektedir. Son olarak, bulgular erken uyarı sistemlerinin geliştirilmesine, şebeke kararlılığının iyileştirilmesine ve güneş enerjisi altyapısının güvenilirliğinin artırılmasına önemli katkılar sağladığını ortaya koymaktadır.

Anahtar Kelimeler: Güneş enerjisi, Ani düşüş olayları, Anomali tespiti, Derin öğrenme.

Giriş

Güneş enerjisi, çevresel etkileri en az olan yenilenebilir ve sürdürülebilir bir enerji kaynağı olarak modern enerji sisteminde önemi zamanla artmıştır. Hem maliyet etkinliği hem de teknolojik gelişmeler güneş enerjisinin yaygınlaşmasını hızlandırmıştır. Fakat güneş enerjisi üretimi, doğası gereği iklim koşullarına ve çevresel faktörlere bağlı olarak değişkenlik göstermektedir. Bu durum enerji arzının istikrarını zorlaştırmaktadır. Ani enerji üretim düşüşleri, enerji arz-talep dengesini bozarak şebeke stabilitesi üzerinde olumsuz etkiler oluşturmakta, bu da yenilenebilir enerji sistemlerinin güvenilirliğini azaltmaktadır. Bu tür ani düşüşlerin nedenleri hem iklimsel değişiklikler hem de sistemsel arızalar örneğin panel yüzeyindeki kirlenme, gölgeleme gibi çeşitli faktörlere dayanmaktadır. Bu karmaşık ve çok değişken yapıya sahip sistemlerde, geleneksel istatistiksel yöntemler sınırlı kalabilmekte bu nedenle daha esnek ve yüksek doğruluklu modeller gerekmektedir. Derin öğrenme, büyük veri setlerinden karmaşık örüntüleri ve ilişkileri otomatik olarak öğrenme yeteneği sayesinde, güneş enerjisi üretimindeki ani ve beklenmedik değişikliklerin tespitinde etkili bir yaklaşım göstermektedir. Özellikle de zaman serisi verilerindeki dalgalanmaları ve anormallikleri algılayabilen derin öğrenme modelleri, enerji üretim sistemlerindeki kritik değişikliklerin erken fark edilmesini sağlamaktadır. Bu çalışmada güneş enerjisi üretimindeki ani düşüşlerin tespiti için derin öğrenme tabanlı yaklaşımlar kullanılarak kapsamlı bir analiz gerçekleştirilmiştir. Fotovoltaik sistemden toplanan veriler üzerinde yapılan deneyler, bu yöntemlerin enerji üretimindeki kritik anormallikleri başarılı şekilde tespit edebileceğini göstermiştir. Elde edilen bulgular, erken uyarı sistemlerinin geliştirilmesi, şebeke stabilitesinin artırılması ve güneş enerjisi altyapısının güvenilirliğinin iyileştirilmesi yönünde önemli katkılar sağlamaktadır.

Literatür Taraması

Bu bölümde literatürdeki ani düşüş ve anomali tespiti yapan çalışmalar incelenmiş ve özetlenmiştir.

Yarat ve Orman'ın yaptığı çalışmada, akıllı sayaçlardan elde edilen 8 yıllık aylık elektrik tüketim verileri kullanılarak anomali tespiti ve tüketim tahmini gerçekleştirilmiştir. Anomali tespiti için Isolation Forest (IF), Local Outlier Factor (LOF) ve FbProphet algoritmaları uygulanmış; tüketim tahmini için ise FbProphet ve XGBoost algoritmaları karşılaştırılmıştır. Verisetinde 25 farklı sayaç yer almakta ve her biri için 102 aylık veri kullanılmıştır. Anomali tespitinde IF algoritması ortalama %16.9, LOF %7.3 ve FbProphet %6.3 oranında anomali belirlemiştir. Tahminleme sonuçlarında ise FbProphet algoritması ortalama %8.37 MAPE değeriyle, XGBoost'un %11.10 MAPE değerine göre daha başarılı sonuç vermiştir (Yarat & Orman, 2023).

Olcay ve arkadaşları bu çalışmada, çevresel faktörler ve panel kirliliğinin güneş enerji santrallerindeki üretim kaybına etkisini analiz etmiştir. Türkiye'nin Kütahya ilinden alınan 180 kWe gücünde çalışan bir santralden 416 gün boyunca toplanan yaklaşık 120.000 saatlik veri kullanılmıştır. Tahmin ve analiz sürecinde iki farklı algoritma kullanılmıştır: Random Forest (RF) regresyon modeli ve Long Short-Term Memory (LSTM) yapay sinir ağı. Çalışmanın sonuçlarına göre RF algoritması %81 doğruluk oranı (R=0.8111) ve RMSE=0.5865 ile tahmin yaparken, LSTM algoritması %97 doğruluk oranı (R=0.9759) ve RMSE=0.2183 ile çok daha başarılı sonuçlar vermiştir (Olcay, Tunca, & Özgür, 2024).

Çetin ve Işık'ın çalışmasında, Humartaş Enerji firmasına ait güneş enerjisi santrallerinden elde edilen yaklaşık 1000 aylık veriyle, LSTM yöntemi kullanılarak bir sonraki ayın elektrik üretimi tahmin edilmiştir. Tahminlerde güneşlenme süresi, hava durumu, panel ve inverter gücü, santral yaşı gibi değişkenler dikkate alınmıştır. LSTM modeli, ocak ayında yaklaşık %13 hata oranı

üretmiş, Mayıs ayında bu oran %1'e kadar düşmüştür. Genel hata oranı %1 ile %15 arasında değişmiştir. Bu sonuç, yöntemin mevsimsel farklılıklara rağmen yüksek doğrulukla çalıştığını ve aylık üretim miktarlarının önceden güvenilir şekilde tahmin edilebildiğini göstermektedir (Çetin & Isık, 2021).

Lim ve arkadaşlarının yaptığı çalışmada, çevresel sensörlere ihtiyaç duymadan sadece geçmiş üretim verileriyle güneş enerjisi tahmini yapan bir CNN-LSTM hibrit model geliştirilmiştir. CNN modeli hava durumunu (güneşli/bulutlu) sınıflandırmış, LSTM ise bu sınıflamaya göre güç üretimini tahmin etmiştir. Veriler, Güney Kore Busan'daki bir güneş enerjisi santralinden 10 Eylül 2019 ile 22 Temmuz 2021 tarihleri arasında toplanmış ve analiz edilmiştir. Elde edilen sonuçlara göre model, güneşli günlerde %4.58 MAPE ve bulutlu günlerde %7.06 MAPE ile oldukça başarılı tahminler yapmıştır. Diğer metriklerde de model yüksek doğruluk göstermiştir: güneşli günlerde MAE 34.00, RMSE 43.87 ve R^2 0.99; bulutlu günlerde MAE 6.97, RMSE 9.09 ve R^2 0.99 olarak raporlanmıştır (Lim, Huh, Hong, Park, & Kim, 2022).

Park ve arkadaşları yaptığı çalışmada, Güney Kore'deki 2517 güneş santralinden toplanan verilerle, anormal verilerin tahmin doğruluğunu bozmasını önlemek için CAE, PCA ve K-means tabanlı bir anomali tespit sistemi geliştirmişlerdir. Tespit sonrası sadece normal verilerle TransLSTM modeli eğitilmiş ve sanal santrallerin tahmin hatası %6.3'ten %4.85'e düşerek %23 iyileşme sağlanmıştır. Anomali tespiti %99.61 doğruluk ve %99.16 F1 skoru ile yüksek başarı göstermiştir (Park, Song, Jeong, & Kim, 2023).

Mulongo ve arkadaşları, Kamerun'daki baz istasyonlarında jeneratör yakıt tüketimindeki anomaliler tespit etmişlerdir. TeleInfra'ya ait 5905 satırlık veride günlük çalışma süresi, tüketilen ve eklenen yakıt gibi bilgiler yer almıştır. SVM, KNN, LR ve MLP algoritmaları karşılaştırılmış, en iyi sonucu MLP vermiştir. MLP, %96.1 doğruluk, %98.8 precision, %95.4 recall ve %99 AUC ile en yüksek başarıyı göstermiştir. Sonuç olarak, yakıt tüketimindeki anomallileri tespit etmede MLP en etkili yöntem olarak belirlenmiştir (Mulongo et al., 2020).

Zangrando ve arkadaşları, üç buzdolabına ait yarı-periyodik enerji tüketim verileriyle toplam 12 farklı anomali tespit algoritması karşılaştırmışlardır. Kullanılan algoritmalar şunlardır: Basic Statistics, AR, ARIMA, LOF, OC-SVM, ISOF, GRU, GRU-MS, LSTM, LSTM-MS, GRU-AE ve LSTM-AE. Veriler akıllı prizlerle dakikalık çözünürlükte toplanmış, anomaliler manuel olarak etiketlenmiştir. En yüksek performans ISOF ile Fridge3 veri setinde elde edilmiştir (Precision = 0.947, Recall = 0.965, F1 = 0.956). Klasik makine öğrenmesi yöntemleri (ISOF, OC-SVM, LOF), GRU ve LSTM tabanlı sinir ağı modellerine göre daha başarılı ve genellenebilir bulunmuştur (Zangrando, Fraternali, Petri, Pinciroli Vago, & Herrera González, 2022).

Başka bir makalede, elektrik enerjisi kullanım verilerinde anomalileri tespit etmek için zaman serilerini görüntüye çevirerek CNN tabanlı bir model geliştirilmiştir. Çalışmada, Güney Kore Enerji Ajansı tarafından sağlanan ve 60 binaya ait saatlik güç tüketimi verilerini içeren bir veri seti kullanılmıştır. Bu verilerden zaman serisi imgeleri (RP, GASF, GADF, MTF) oluşturulmuş ve bu imgelerle anomali tespiti yapılmıştır. Veriler k-means, k-shapes ve SOM algoritmalarıyla önceden kümeleme işlemine tabi tutulmuş, ardından her küme için ayrı CNN modelleri eğitilmiştir. Karşılaştırma için ARIMA modeli de uygulanmıştır. Sonuçlara göre, MTF algoritmasıyla oluşturulan zaman serisi görüntüleri ve CNN ile yapılan anomali tespiti en iyi sonucu vermiştir (F1-score = 0.97, SOM kümeleme ile) (Oh, Oh, Um, Kim, & Jung, 2022).

Materyal ve Metot

Bu bölümde çalışmada kullanılan veri kümesi, derin öğrenme modelleri ve metrikler açıklanmış ve sunulmuştur.

Kullanılan Veri Seti

Bu çalışmada Kahramanmaraş ilinde bulunan İbrahim Taşyurdu GES'e ait üretim verisi kullanılmıştır. Kahramanmaraş ili, Pazarcık ilçesi, Memişkahya Mahallesi 906 ada, 3 parsel içerisinde işletme çatısı üzerinde bulunan 469,2 kWe kurulu gücündeki (İbrahim Taşyurdu GES) güneş enerjisi santrali baz alınmıştır.

Bu çalışmada ilk adım olarak kullanılacak olan veri seti oluşturulmuştur. Veri seti, gerçek saha koşullarından elde edilmiş olup 2 Sütun ve 35055 satırdan oluşmaktadır. Toplamda dört yıllık güneş enerjisi üretim verilerini içermektedir. 01.01.2019 tarihinden başlayarak 31.12.222 tarihine kadar devam eden günlük üretim verilerinden oluşmaktadır. Çalışma boyunca gerçekleştirilen deneyler bu veri seti üzerinden yürütülmüştür. Aşağıdaki Tablo 1'de veri setindeki günlük üretim örneği sunulmuştur.

Tablo 5. Günlük Üretim Verisi

Profil Tarihi	Üretim
01/01/2019 00:00:00	0
01/01/2019 01:00:00	0
01/01/2019 02:00:00	0
01/01/2019 03:00:00	0
01/01/2019 04:00:00	0
01/01/2019 05:00:00	0
01/01/2019 06:00:00	0
01/01/2019 07:00:00	0
01/01/2019 08:00:00	10
01/01/2019 09:00:00	10
01/01/2019 10:00:00	20
01/01/2019 11:00:00	30
01/01/2019 12:00:00	30
01/01/2019 13:00:00	10
01/01/2019 14:00:00	20
01/01/2019 15:00:00	10
01/01/2019 16:00:00	0
01/01/2019 17:00:00	0
01/01/2019 18:00:00	0
01/01/2019 19:00:00	0
01/01/2019 20:00:00	0
01/01/2019 21:00:00	0
01/01/2019 22:00:00	0
01/01/2019 23:00:00	0

Derin Öğrenme Modelleri

Bu çalışmada rampdown (ani düşüş) olaylarını tespit etmek için BILSTM, LSTM (Alpay, 2020; Er & Işık, 2021) ve GRU (Demirci & Karaatlı, 2023; Tunç & Erdem, 2024) tabanlı derin öğrenme modelleri kullanılmıştır. Aşağıda çalışmada kullanılan derin öğrenme modelleri açıklanmıştır.

Long Short-Term Memory (LSTM): tekrarlayan sinir ağı (RNN) tabanlı bir derin öğrenme mimarisidir. İçerisinde bilgi akışını yöneten giriş, unutma ve çıkış kapılarından oluşan özel

LSTM hücreleri bulunur. Bu yapı, zamanla değişen verilerde uzun vadeli bağımlılıkları öğrenmede etkilidir.

Bidirectional LSTM (BiLSTM): BiLSTM sinir ağı, verileri iki LSTM üzerinden zıt yönlerde ileri ve geri işleyebilir. Geçmiş ve gelecek bilgileri kullanarak eğitilmektedir.

Gated Recurrent Unit (GRU): standart tekrarlayan sinir ağının geliştirilmiş bir versiyonudur. GRU'lar kaybolan gradyan problemi (vanishing gradient problem)'ni çözmek amacıyla geliştirilmiştir. GRU, LSTM'in bir varyasyonu olarak da düşünülebilir çünkü her ikisi de benzer şekilde tasarlanmış ve bazı durumlarda eşit derecede başarılı sonuçlar verebilen ağ yapılarıdır. İkisinde de temel amaç aynıdır. LSTM'ler ve GRU'lar kısa süreli belleğe çözüm olarak oluşturulmuşlardır. Bilgi akışını düzenleyebilen "kapı (gate)" adı verilen iç mekanizmalara sahiptirler. Ancak GRU'lar da bir çıkış kapısı mevcut olmadığı için LSTM'den daha az parametresi bulunmaktadır. GRU'nun iki geçit mekanizması vardır: sıfırlama kapısı ve güncelleme kapısı. Sıfırlama kapısı gizli durumun unutulması gerektiği miktarını belirler, güncelleme kapısı ise gizli durumu güncellemek için yeni girişin miktarını belirler.

Performans Metrikleri

Model değerlendirmesinde kullanılan MAE, MSE ve R^2 hata metrikleri aşağıda açıklanmıştır. Bu çalışmada kullanılan metriklerde, denklemler (1)–(3)'de, y_i gerçek değeri, $\widetilde{y_i}$ tahmin edilen değeri, $\overline{y_i}$ gerçek değerlerin ortalamasını ve n gözlem sayısını ifade etmektedir.

- **Mean Absolute Error (MAE)**

Gerçek ile tahmin edilen değerler arasındaki mutlak farkların ortalamasını hesaplamaktadır. Denklem (1)'deki gibi hesaplanmaktadır.

$$MAE = \frac{1}{n}\sum_{i=1}^{n} | y_i - \widetilde{y_i} | \tag{1}$$

- **Mean Squared Error (MSE)**

Ortalama mutlak hata, her bir verinin model performansına eşit ağırlık verdiği bir metriktir. Denklem (2)'deki gibi hesaplanmaktadır.

$$MSE = \frac{1}{n}\sum_{i=1}^{n} (y_i - \widetilde{y_i})^2 \tag{2}$$

- **R-Squared (R^2)**

Bağımsız değişkenlerin bağımlı değişkendeki varyasyon oranı ile bulunmaktadır. Denklem (3)'te görüldüğü gibi hesaplanmaktadır.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \widetilde{y_i})^2}{\sum_{i=1}^{n}(y_i - \overline{y_i})^2} \tag{3}$$

Bulgular ve Tartışma

Bu çalışmada, üretim verileri üzerinde rampdown noktalarının tahmin edilmesi amacıyla BiLSTM, LSTM ve GRU tabanlı derin öğrenme modelleri eğitilmiştir. Modellerin

performansları hem performans metrikleri hem de tahmin edilen rampdown noktalarının doğruluğu açısından analiz edilmiştir. Modellerin eğitim sürecinde, ardışık 20 epoch boyunca eğitim gerçekleştirilmiştir.

Rampdown olayı tespiti için, iki veri noktası arasındaki üretim farkı değeri eğer bir eşik değerinden düşük ise bu nokta rampdown noktası olarak seçilmiştir. Sonrasında zaman serisi halindeki verilerin makine öğrenmesine uygun hale getirilmesi için kayan pencere yapısından faydalanılmıştır. Bunun için de pencere boyutu 48 olarak belirlenmiştir. Yani veride 48 input 1 output olacak şekilde format değişikliği yapılmıştır. Ardından üretim verisinin ilk %80'lik kısmı eğitim, geriye kalan %20'lik kısmı ise test olarak ayrılmıştır. Ayrıca eğitim verisinin %20 de doğrulama verisi olarak belirlenmiştir. Daha sonra 3 katmanlı ve 64x32x32 nöronlara sahip derin öğrenme modelleri ile algoritma eğitilmiştir. Bu süreçte Adam optimizer ve MAE hata metriğinden faydalanılmıştır. Test verisi ile de modellerin öğrenme performansları test edilmiştir. Ardından tahmin edilen test verisinde iki veri noktası arası üretim farkı aynı eşik değerinden yüksek ise bu nokta rampdown olarak belirlenmiş ve gerçek rampdown noktaları ile karşılaştırılmıştır.

Aşağıda bulunan Tablo 2'de derin öğrenme modellerinin veri seti üzerindeki performanslarının karşılaştırması verilmiştir.

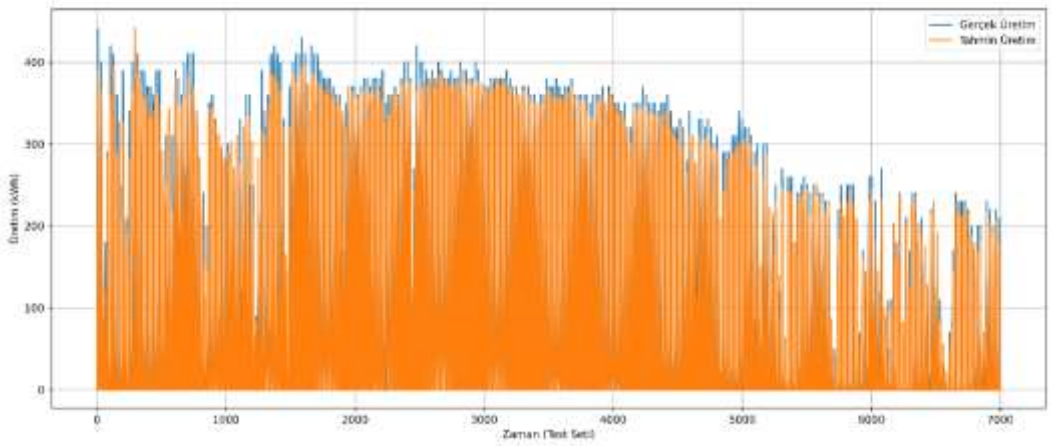
Tablo 6. Derin Öğrenme Modellerinin Üretim Tahmini İçin Performans Karşılaştırması

Algoritmalar	MAE	MSE	R^2
LSTM	9.6	482.03	0.971
GRU	9.72	489.6	0.97
BiLSTM	10.34	498.28	0.97

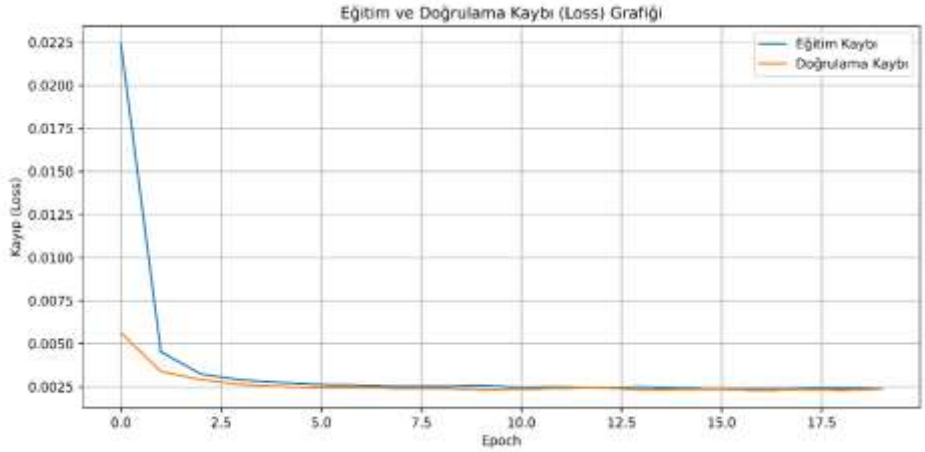
Şekil 1'te, BiLSTM modelinin test veri seti üzerindeki üretim tahminleri ile gerçek üretim değerleri karşılaştırılmaktadır. Mavi çizgi gerçek üretimi, turuncu çizgi ise model tarafından tahmin edilen üretimi göstermektedir.

Şekil 2'de, BiLSTM modelinin eğitim sürecindeki kayıp (loss) değerlerinin epoch bazında değişimi gösterilmektedir. Mavi çizgi eğitim kaybını, turuncu çizgi ise doğrulama kaybını temsil etmektedir.

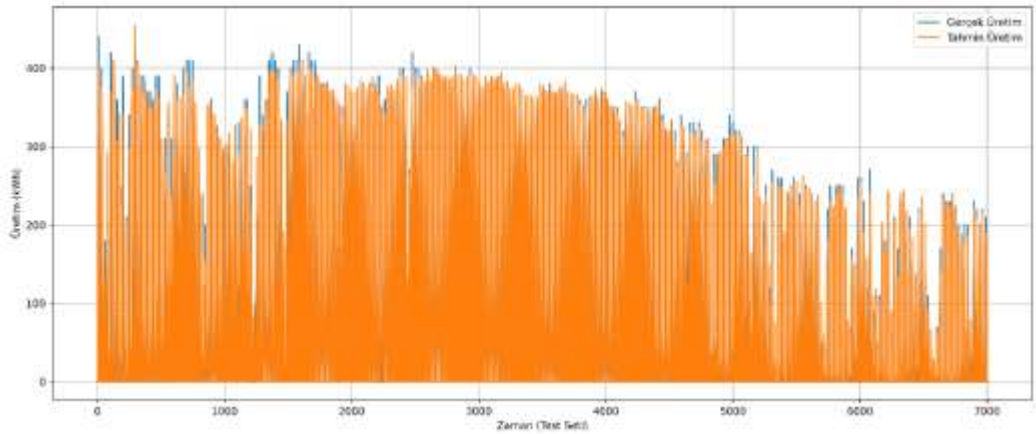
Şekil 3'te, LSTM modelinin test veri seti üzerindeki üretim tahminleri ile gerçek üretim değerleri karşılaştırılmaktadır.



Şekil 5. BİLSTM ile Tahmin Edilen Üretim Değerleri



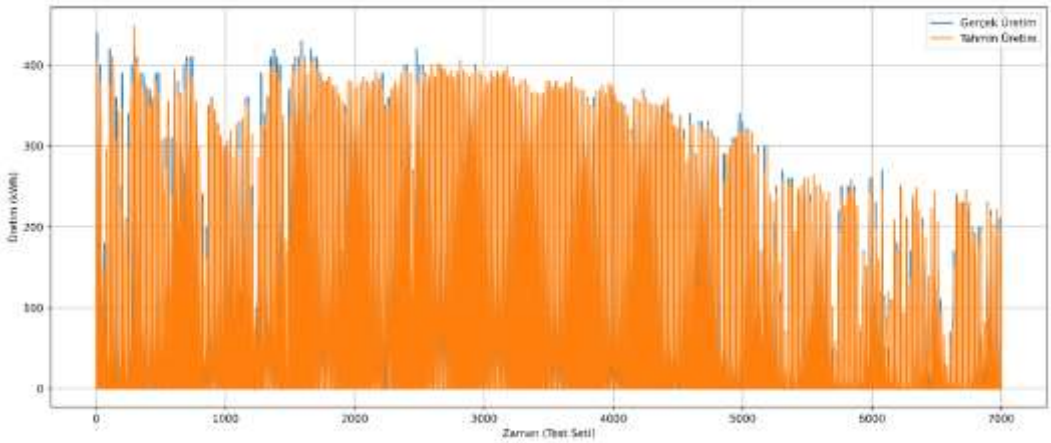
Şekil 6. BiLSTM Modelinin Eğitim-Doğrulama Kayıp Grafiği



Şekil 3. LSTM ile Tahmin Edilen Üretim Değerleri

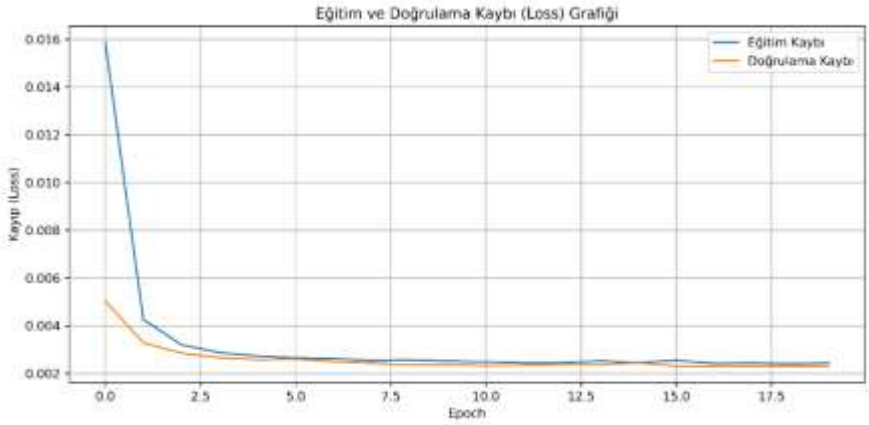
Şekil 4'de ise LSTM modelinin eğitim sürecindeki kayıp (loss) değerlerinin epoch bazında değişimi gösterilmektedir.

Şekil 5'te, GRU modelinin test veri seti üzerindeki üretim tahminleri ile gerçek üretim değerleri karşılaştırılmaktadır.



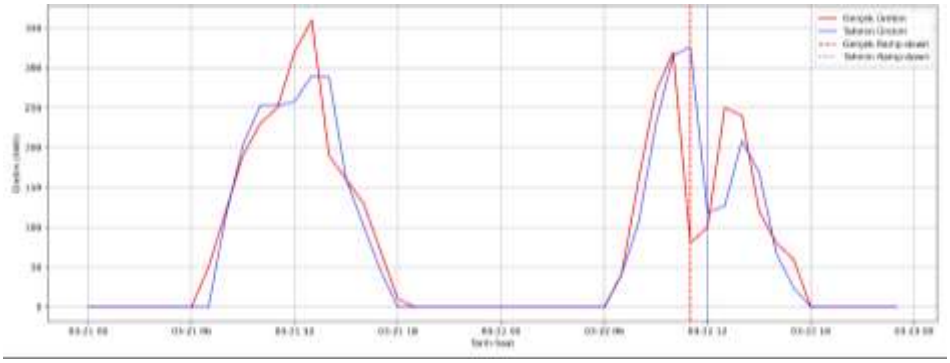
Şekil 5. GRU ile Tahmin Edilen Üretim Değerleri afiği

Şekil 6'de ise GRU modelinin eğitim sürecindeki kayıp (loss) değerlerinin epoch bazında değişimi gösterilmektedir.

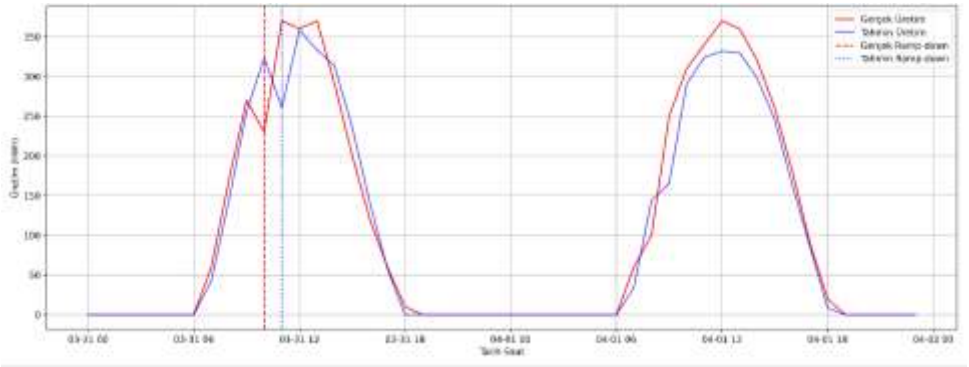


Şekil 6. GRU Modelinin Eğitim-Doğrulama Kayıp Grafiği

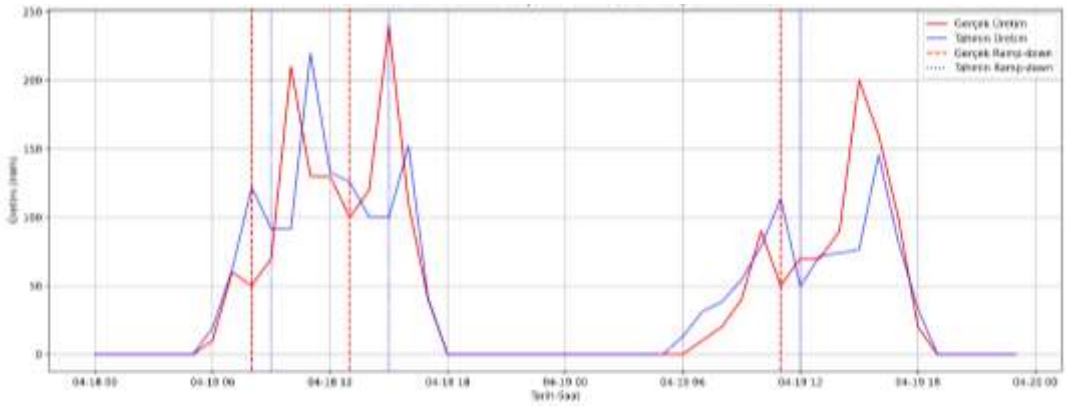
Şekil 7, Şekil 8 ve Şekil 9'da sunulan örnek grafiklerde yapılan tahmin sonrası elde edilen rampdown örnekleri verilmiştir. Bu grafiklerde dikey kırmızı noktalar gerçek verideki rampdown noktalarını, mavi dikey noktalar ise tahmin edilen üretim değerindeki rampdown noktasını göstermektedir. Şekil 10'da ise hem gerçek üretim de hem de tahmin edilen üretimde bir rampdown tespit edilmediği görülmektedir.



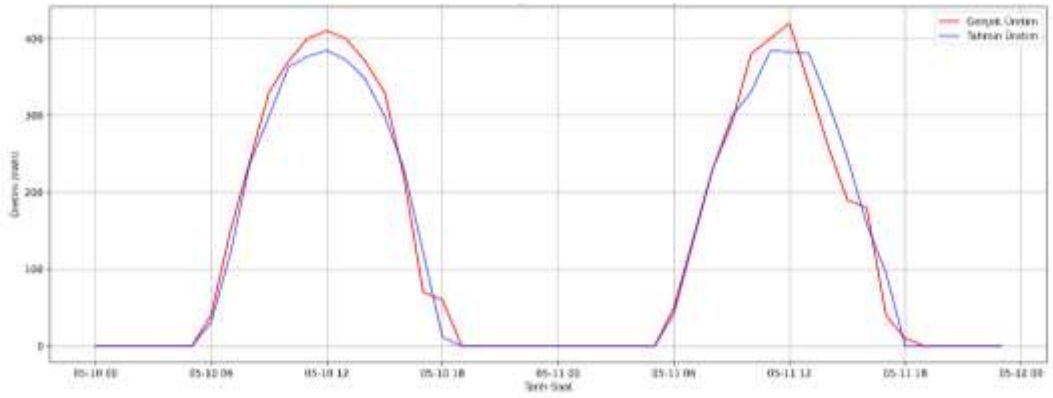
Şekil 7. Rampdown Örnek-1



Şekil 8. Rampdown Örnek-2



Şekil 9. Rampdown Örnek-3



Şekil 10. Rampdown Örnek-4

Sonuç ve Öneriler

Bu çalışmada rampdown olaylarını tespit için BILSTM, LSTM ve GRU tabanlı derin öğrenme modelleri kullanılmıştır. Modeller, 509 rampdown noktasını içeren bir veri kümesi üzerinde eğitilmiş ve test edilmiştir. Gerçek eğitim verisinde 413 nokta, test verisinde ise 96 nokta rampdown olarak belirlenmiştir. Deneysel çalışmalarda elde edilen sonuçlar aşağıda karşılaştırılmıştır.

Yapılan tahmin işleminde BILSTM modeli sonrası test verisinde 87 rampdown tahmininde bulunmuş ve bunlardan 60 tanesi gerçek rampdown ile yaklaşık olarak uyuşmuştur. Ortalama sapma süresi farkı 1.29 saat olarak ölçülmüştür. MSE: 498.28 MAE: 10.34 ve R^2 skoru: 0.97 olarak hesaplanmıştır. LSTM modeli ile yapılan tahmin işlemi sonrası 85 rampdown tahmininde bulunmuş ve bunlardan 64 tanesi gerçek rampdown ile yaklaşık olarak uyuşmuştur. Bu işlemde ise ortalama sapma süresi farkı 1.29 saat olarak ölçülmüştür. MSE: 482.03 MAE: 9.6 ve R^2 skoru: 0.971 olarak hesaplanmıştır. GRU modeli yapılan tahmin işleminde ise 87 rampdown tahmininde bulunmuş ve bunlardan 65 tanesi gerçek rampdown ile yaklaşık olarak uyuşmuştur. Ortalama süre farkı 1.47 saat olarak ölçülmüştür. MSE: 489.6 MAE: 9.72 ve R^2 skoru: 0.97 olarak hesaplanmıştır.

Bu çalışma sonucunda ise LSTM modeli, en düşük MSE ve MAE değerlerini vererek üretim tahmininde en başarılı sonucu vermekte ve ayrıca gerçek rampdown durumu ile tahmin edilen rampdown olayı arası ortalama en düşük 1.29 saat ile en iyi algoritma olmuştur. Gelecekte veri üzerinde farklı önişlemler, farklı algoritmalar kullanılarak modellerin performanslarının iyileştirilmesi amaçlanmaktadır.

Teşekkür ve Bilgi Notu

Bu çalışma kapsamında üretim verilerini paylaşarak çalışmaya katkı sağlayan Kahramanmaraş ilinde bulunan İbrahim Taşyurdu Güneş Enerji Santrali'ne teşekkür ederiz. Çalışma süreci boyunca sağlanan veriler önemli katkı sağlamıştır.

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PARKINSON'S DISEASE AND NURSING MANAGEMENT

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ABSTRACT

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by primary motor symptoms such as bradykinesia, muscular rigidity, resting tremor, and postural instability, resulting from the degeneration of the substantia nigra and subsequent reduction or loss of dopamine-producing neurotransmitters. The disease affects all ethnic groups worldwide and occurs in both sexes, though it is slightly more prevalent in men. Due to the complexity of the disease and the limited treatment options, managing Parkinson's disease poses significant challenges for both patients and caregivers. Effective collaboration between physicians and nurses enables a more integrated and ultimately higher-quality care approach. There is evidence suggesting that care provided by trained nurses leads to better health outcomes across various disorders, including Parkinson's disease. The scope of nursing care should include patient and caregiver education, support for self-management, guidance on sexual health, and psychosocial support. Paying attention to these aspects in nursing interventions is anticipated to improve the quality of life in individuals with Parkinson's disease. This review addresses key components of nursing management in patients with Parkinson's disease and highlights the critical role nurses play in delivering holistic and patient-centered care.

Keywords: Nursing, Nursing management, Parkinson, Parkinson's disease

PARKİNSON HASTALIĞINI VE HEMŞİRELİK YÖNETİMİ

ÖZET

Parkinson hastalığı, hareket fonksiyonunda rol alan substansiya nigranın dejenerasyonu ile dopamine üreten nörotransmitterlerin azalması veya yok olması sonucunda ortaya çıkan; bradikinezi, kas sertliği, istirahat titremesi ve duruş bozukluğu gibi birincil motor semptomlarıyla karakterize, progresif, nörodejeneratif bir hastalıktır. Hastalık tüm dünyada, tüm etnik gruplarda görülür ve her iki cinsiyeti de eşit şekilde etkiler ancak erkeklerde biraz daha baskınlık vardır. Hastalığın karmaşıklığı ve sınırlı tedavi seçeneklerinden dolayı, Parkinson hastalığının yönetimi ve hastalar ile bakım sağlayıcılar için hastalıkla başa çıkma konusunda ciddi zorluklar yaratmaktadır. Doktorlar ve hemşireler arasındaki işbirliği, daha bütünleşik ve sonuç olarak daha kaliteli bir bakıma olanak sağlar. Eğitimli hemşireler tarafından sağlanan bakımın çeşitli bozukluklar için daha iyi sağlık sonuçları sağlayabileceğine yönelik kanıtlar bulunmaktadır. Sağlanacak olan hemşirelik bakımının içeriğinde bilgi vermek, hasta ve bakım sağlayıcısına öz yönetimde destek olmak, cinsel hayata yönelik bilgi ve eğitim, psikososyal destek sağlamak gibi başlıklardan söz edilebilir. Hemşirelik bakımında bu hususlara dikkat edilmesi halinde hastaların yaşam kalitelerinin de artacağı öngörülmektedir. Bu derlemede Parkinson hastalarında hemşirelik yönetimine yönelik bilgiler ele alınmıştır.

Anahtar Kelimeler: Hemşirelik, Hemşirelik yönetimi, Parkinson, Parkinson hastalığı

Giriş

Parkinson hastalığı (PH), ilk kez 1817'de İngiliz Doktor James Parkinson tarafından "titrek felç" olarak tanımlamıştır. PH, orta beyinde özelleşmiş ve hareketten sorumlu olan "substansiya nigra"nın dejenerasyonuyla birlikte dopamin üretiminin azalması veya hiç olmaması sonucunda gelişen nörodejeneratif bir hastalıktır (Şen ve ark., 2023). PH, motor ve non motor semptomlar ile kendini göstermektedir. Motor semptomlara bakıldığında, rijidite, bradikinezi, titreme ve postüral instabilite görülmektedir. Non motor semptomlar arasında ise aşırı tükürük salınımı, görme sorunları, uyku bozuklukları, cinsel disfonksiyon, konstipasyon, ağrı, demans ve depresyon bulunmaktadır (Civil, 2018; Postuma ve ark., 2015). Motor semptomlar hastalığın teşhisi için önemlidir. Bilişsel bozukluk, uyku bozuklukları ve duygudurum bozukluklarına yönelik non motor semptomlar ise daha erken dönemde başlayabildiği için hastalığın erken teşhisini zorlaştırmaktadır (Poewe ve ark., 2017; Schapira ve ark., 2017). Beyindeki dopaminerjik nöron kaybına bağlı olarak hastalarda, harekette yavaşlama ve kas kasılmaları görülmeye başlamaktadır (Şen ve ark., 2023).

PH, sıklıkla 40-75 yaş arasındaki bireylerde görülmektedir. Yaşın ilerlemesiyle birlikte, PH'na yakalanma olasılığı artmaktadır (Civil, 2018). Hastalığın 65 yaş ve üzeri bireylerde görülme sıklığı %2-3 oranlarındadır (Poewe ve ark., 2017). Küresel Hastalık Yükü Araştırması'na göre 2040 yılından itibaren 12,9 milyon kişinin Parkinson hastalığından etkilenebileceğini öngörmektedir (Dorsey ve Bloem, 2018). Yaşın yanı sıra cinsiyette önemli bir etkendir. Erkeklerde kadınlara oranla 2 kat daha fazla görülmektedir (Savica ve ark., 2013). Ancak kadınlarda hastalık daha hızlı ilerlemekte olup, mortalite oranı daha yüksektir (Cerri ve ark., 2019).

Alzheimer'dan sonra en sık görülen nörodejeneratif hastalık olan PH'nın prevelansı ülkeden ilkeye değişiklik göstermektedir (İbrahimoğlu ve ark., 2019; Parkinson Hastalığı Derneği, 2013). Türkiye'nin batısında yapılan bir çalışmada PH prevelansı %1.2 olarak belirlenmiştir (Güler ve ark., 2022).

Tedavi

PH'da tedavinin amacı yaşam kalitesini en üst düzeye çıkarmak ve hastalığa bağlı gelişen sakatlığı en aza indirmektir. Bu nedenle tedavi sadece semptomlara yönelik ve hasta merkezli olmalıdır (GPDS, 2002; Öksüz ve ark., 2022). Tedavi, motor ve/veya non motor semptomlar fiziksel veya sosyal engelliliğe yol açmaya ve yaşam kalitesini bozmaya başladığında başlatılmalıdır (Grosset ve ark., 2007).

Farmakolojik, non farmakolojik, cerrahi tedaviler kullanılmaktadır. Bu tedavi çeşitleri hastaların ihtiyaçlarına ve hastalık düzeyine göre düzenlenmektedir (Kaya ve ark., 2022).

Farmakolojik tedaviler içerisinde, dopamin agonistleri, levodopa (levodopa-karbidopa veya levodopa-benserazid) ve monoamin oksidaz (MAO)-B inhibitörleri, antikolinerjikler, katekol-O-metiltransferaz inhibitörleri ve amantadin gibi ilaçlar bulunmaktadır (Hayes ve ark., 2019). Bu ilaçlar hastalığın motor semptomlarına yönelik olup hastaların günlük yaşam aktivitelerini devam ettirmelerini sağlamaktadır (Ahlskog ve ark., 2001).

Farmakolojik tedaviden yanıt alınamayan ileri evre Parkinson hastalarında cerrahi tedaviye başvurulabilmektedir. İleri evre PH'da tremor, rijidite ve bradikinezi gibi semptomlarda iyileşme sağlayan Derin Beyin Stimülasyonu (DBS), ilaç yan etkilerinin de azalmasını sağlayarak hastaların yaşam kalitelerini de artırmaktadır (Rizek ve ark., 2016; Yiğit ve ark., 2015; Pringsheim ve ark., 2021).

Farmakolojik ve cerrahi tedavinin yanı sıra uygulanan non farmakolojik tedaviler de hastalığın yönetiminde büyük önem taşımaktadır. Uygulanan yöntemler hastalığın motot ve non motor semptomlarının yönetiminde önemlidir (Rutz ve ark., 2020). PD'de yürümeyi, dengeyi ve düşmeleri iyileştirmek için denge, direnç ve aerobik egzersiz, koşu bandında yürüme, hareket stratejisi eğitimi, dans (özellikle partnerli dans) ve Tai Chi dahil olmak üzere bir dizi farklı egzersiz ve fizik tedavi denenmiştir. Sistematik incelemeler denge, hareketlilik ve kas gücünde gelişmeler olabileceğini doğrulamaktadır (Kim ve ark., 2018). Farmakolojik tedavi ve non farmakolojik tedavinin birlikte kullanılması semptom kontrolünde önemlidir. İkisinin birlikte kullanılması ile iyileşme potansiyeli artmaktadır (Çağlar ve ark., 2005).

Hemşirelik Yönetimi

Hastalar günlük yaşam aktivitelerini yaparken yarı veya tam bağımlı olabilmekte ve buna bağlı olarak yaşam kaliteleri de olumsuz etkilenmektedir (Şen ve ark., 2023; Wressle ve ark., 2007; Yazar ve ark., 2017). Bu nedenle hasta ve ailesinin yaşamında bakım yükü artmakta, bununla birlikte birçok sorun ortaya çıkmaktadır.

Mevcut tedavi seçenekleri, hastaların ve bakım vericilerin yaşam kalitesini artırmak için PH semptomlarını kontrol etmeye odaklı bir dizi disiplinlerarası eylem gerektirse de (Radder ve ark., 2019; van der Marck ve ark., 2013), bu PH'da karşılanmamış bir ihtiyaç olmaya devam etmektedir. Bu nedenle, multidisipliner ekip çalışması ile bütünleşik yaklaşımların benimsenmesine ihtiyaç vardır. Multidisipliner ekibin en önemli üyelerinden biri olan hemşirenin; sağlığı geliştirmek, hastalığa bağlı gelişen sınırlılıklara uyum sağlamak ve komplikasyonların tedavisi gibi konularda rolleri bulunmaktadır (Tosin ve ark., 2016).

Kanıta dayalı çalışmalarda sistematize edilmiş hemşirelik bakımının, PH'nın motor ve non motor semptomlarını kontrol etmede, disiplinler arası müdahalelerin etkinliğini artırmada kritik bir faktör olabileceği gösterilmiştir (Connor ve ark., 2019; Jones ve ark., 2016).

PH'da hemşirelik bakımı genel olarak; hasta ve ailesinin bilgilendirilmesi ve desteklenmesi, tedavi rejiminin düzenli takibi, rehabilitasyon ve destek hizmetinin sağlanması, yaşam kalitelerinin iyileştirilmesi için gerekli hizmetlerin sunulması, psikolojik ihtiyaçlarının karşılanması, fiziksel güvenliğin sağlanması gibi alanları kapsamaktadır (Zhao ve ark., 2020). Bu bağlamda hemşire, Parkinson tanısı alan bireye hastalıkla baş etmede, bağımlılık halini en aza indirmesine ve bağımsız bir şekilde hareket edebilmesine yardımcı olmalıdır (Durna ve ark., 2012).

Hemşirelik bakım planında genel olarak fiziksel mobilitede bozulma, öz bakım eksikliği, sözel iletişimde bozulma, konstipasyon, üriner boşaltımda bozulma, uyku örüntüsünde rahatsızlık, etkisiz baş etme gibi tanılar yer almaktadır. Bakım planı hasta merkezli olup, bireyin gereksinimleri doğrultusunda planlanmalıdır (Durna ve ark., 2012).

Hastaların ihtiyaçlarına göre ilaç kullanımına yönelik bilgilendirme yapılmalıdır. Özellikle ilaçların besinlerle ve diğer ilaçlarla etkileşimi, aç veya tok karnına alınması gibi durumlara yönelik bilgiler verilmelidir (Woodward ve ark., 2013; Civil, 2018).

PH'da egzersiz çok önemli bir unsurdur. İlerleyen evrelerde postürde bozulmalar olabileceği için hastaya özgü egzersiz eğitimi, hasta ve ailesine verilmelidir. Düşme riski için ekstra önlemler alınmalıdır. Uyku örüntüsündeki rahatsızlıklara yönelik gün içerisinde kısa uyku ve dinlenme periyotları uygulanmalıdır. Yaşanabilecek ağrılara yönelik farmakolojik yöntemlerin yanında non farmakolojik yöntemlere yönelik de eğitim verilmelidir. Konstipasyonu önlemeye yönelik gerekli bilgilendirmeler yapılmalı, var olan konstipasyon için girişimler planlanarak

uygulanmalıdır. Anksiyete, depresyon ve cinsel işlev bozukluğu sorgulanarak, olası durumda gerekli girişimler ve yönlendirmeler sağlanmalıdır (Civil, 2018).

Sonuç

Progresif bir seyir gösteren PH, yaşam kalitesini de olumsuz etkilemektedir. Yaşam kalitesinin optimal seviyede olabilmesi, tedavi seçeneklerinin doğru bir şekilde uygulanması, hasta ve ailesinin eğitimi için hemşirelik yönetimi ciddi derecede önem arz etmektedir. Doğru hemşirelik bakımının planlanması ve uygulanması bu açıdan önemlidir.

PH'na yönelik uzman hemşirelerin yetiştirilmesi, müfredatların buna yönelik düzenlenmesi, konuya yönelik eğitimlerin yapılmasının verimli olacağı düşünülmektedir. Ayrıca hemşirelik bakımına yönelik akademik çalışmaların genişletilerek yapılması, sonuçların paylaşılması ve yeni gelişmelerin takip edilmesi önerilmektedir.

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DIGITAL TWIN BASED DISTRIBUTION NETWORK MANAGEMENT: INTEGRATION OF GIS, SCADA AND AMR

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ABSTRACT

This study addresses the integration of digital twin technology with GIS (Geographic Information System), SCADA, and AMR (Automatic Meter Reading) data in the management of electrical distribution networks. The main objective is to improve grid observability, intervention speed, and energy efficiency. GIS data enabled the spatial modeling of the network, SCADA integration ensured real-time monitoring, and AMR data made it possible to perform consumption-based analysis and detect losses or unauthorized usage. A specially designed table structure based on Oracle Spatial was developed to optimize data processing time. The integration process has provided significant benefits in enhancing grid performance, improving fault management, and activating user notification systems. The results demonstrate that AI-supported digital twin models can serve as an innovative management tool in modern energy systems.

Keywords: Digital Twin, Geographic Information System (GIS), SCADA, OSOS Data

DİJİTAL İKİZ TABANLI DAĞITIM ŞEBEKESİ YÖNETİMİ: CBS, SCADA VE OSOS ENTEGRASYONU

ÖZET

Bu çalışmada, elektrik dağıtım şebekelerinin yönetiminde dijital ikiz teknolojisinin CBS (Coğrafi Bilgi Sistemi), SCADA ve OSOS (Uzaktan Sayaç Okuma Sistemi) verileri ile entegrasyonu ele alınmıştır. Amaç, dağıtım şebekesinin izlenebilirliğini, müdahale hızını ve enerji verimliliğini artırmaktır. CBS verileri sayesinde şebekenin mekânsal yapısı modellenmiş, SCADA entegrasyonu ile gerçek zamanlı izleme sağlanmış, OSOS verileriyle tüketim bazlı analiz ve kayıp-kaçak tespiti mümkün hale getirilmiştir. Oracle Spatial altyapısında geliştirilen özel tablo yapısı ile veri işleme süresi optimize edilmiştir. Entegrasyon süreci, şebeke performansının artırılması, arıza yönetiminin iyileştirilmesi ve kullanıcı bilgilendirme sistemlerinin etkinleştirilmesi açısından büyük faydalar sunmuştur. Sonuçlar, yapay zekâ destekli dijital ikiz modellerinin enerji sistemlerinde yenilikçi bir yönetim aracı olabileceğini göstermektedir.

Anahtar Kelimeler: Dijital İkiz, Coğrafi Bilgi Sistemi (CBS), SCADA, OSOS Data

Giriş

Elektrik dağıtım şebekeleri, toplumsal yaşamdaki enerji talebinin sistematik ve güvenilir bir şekilde karşılanmasında kritik bir rol oynamaktadır. Güvenli ve verimli bir şebeke yönetimi, yalnızca yaşam kalitesini artırmakla kalmayıp, ekonomik büyüme ve sürdürülebilir kalkınma açısından da önemli bir zemin oluşturmaktadır. Ancak, iklimsel koşullar, yenilenebilir enerji kaynakları, cihaz ve şebeke hasarları, arıza yönetimi ile veri entegrasyonu gibi zorluklar, elektrik şebeke yönetimin karmaşıklığını artırmaktadır. Bu karmaşıklığın giderilmesi, elektrik enerji ihtiyacının artması, şebekenin modernize edilmesi ve mevcut şebekeye güneş, rüzgar, hidroelektrik gibi yenilenebilir enerji kaynaklı santrallerin eklenmesi ile birlikte yenilikçi çözümler bulunmaya çalışılmaktadır. Mevcut sistemlerden (CBS, SCADA, OMS, DMS, OSOS vb.) elde edilen veriler, elektrik şebekesi için entegre edilmediği takdirde şebekenin dağıtım tarafında operasyonel verimliliği düşürebilmektedir [1, 2]. Bundan kaynaklı kesinti durumu, arıza tespiti, müdahale edilebilmesi ve şebeke kullanıcılarının bilgilendirilmesi gibi yapılması gereken çalışmalarda aksamalar meydana gelebilmektedir [3].

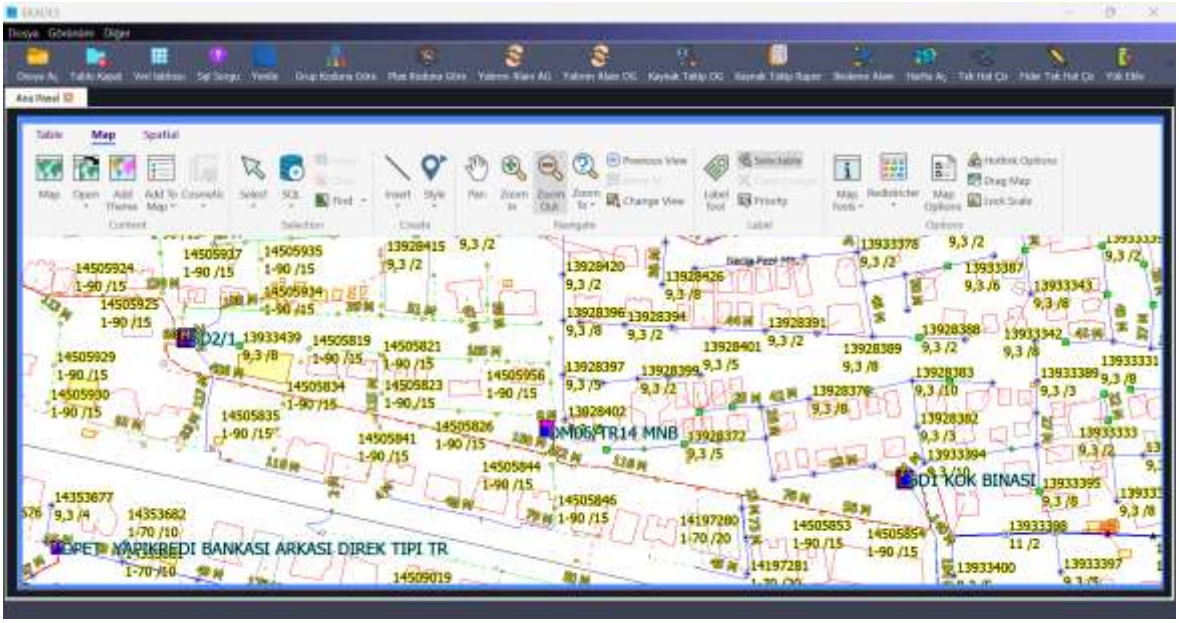
Bu çalışmada, dağıtım şebekelerinin yönetiminde kullanılan mevcut sistemlerin (CBS, SCADA, OMS, DMS, SAP, OSOS, INAVITAS) dijital ikiz teknolojisi ile entegrasyonu ve yapay zekâ desteği ile güçlendirilmesi gerektiği vurgulanmaktadır. Bu kapsamda, şebeke işletme kalitesinin artırılmasına yönelik bir yazılım uygulaması hayata geçirilmiştir. Dijital ikiz teknolojisinin elektrik dağıtım şebekelerindeki uygulamalarını ve bu teknolojinin sunduğu yenilikçi modelleme ve benzetim özelliklerini teorik olarak ele alır.

Bu kapsamda, enerji sistemlerinin yönetiminde yenilikçi teknolojilerin nasıl daha etkili kullanılabileceğine dair yeni bilgiler ve yaklaşımlar sunulmaktadır. Sonuç olarak, OSOS verilerinin dijital ikiz modeline entegrasyonu, elektrik dağıtım şebekelerinin daha etkin bir şekilde yönetilmesine imkân sağladığı görülmüştür. Bu entegrasyon, şebeke performansının izlenmesi, enerji tüketiminin yönetilmesi ve operasyonel verimliliğin artırılması açısından büyük avantajlar sunar.

Coğrafi Bilgi Sistemi Verilerinin Entegrasyonu

Coğrafi Bilgi Sistemleri (CBS) verileri, elektrik dağıtım şebekelerinin coğrafi konumlarını, altyapı bileşenlerini ve bu bileşenlerin mekânsal ilişkilerini içeren kritik bilgiler sağlar. CBS, elektrik dağıtım şebekesinin fiziksel varlıklarını haritalandırarak, şebekenin daha iyi yönetilmesine ve optimizasyonuna olanak tanır. Bu veriler, dijital ikiz modellerinin oluşturulması ve etkin bir şekilde çalıştırılması için temel bir bileşen olarak vazife görür. CBS verilerinin doğru ve kapsamlı bir şekilde entegrasyonu, şebeke yönetiminde büyük avantajlar sağlar. CBS verilerinin dijital ikiz modeline entegrasyonu, birkaç aşamadan oluşur. İlk aşamada, mevcut CBS verileri temel veri kaynağı kabul edilerek veri tabanı düzeyinde ve geliştirilen yazılımda gerekli entegrasyon altyapısı oluşturulur. CBS verileri, genellikle çeşitli formatlarda ve farklı veri kaynaklarından gelir. Bu nedenle, veri entegrasyonu sürecinde veri formatlarının uyumlu hale getirilmesi ve veri kalitesinin doğrulanması önemlidir.

Bu çalışma kapsamında geliştirilen sistemdeki dijital ikizin CBS ile entegrasyonuna ait uygulama örnek ekran görüntüsü aşağıdaki Şekil 1'de bulunmaktadır. Bu şekilde dağıtım binaları, yüksek gerilim hatları (kırmızı), alçak gerilim hatları (mavi), direkler(nokta), rekortmenler ve elektrik tüketimi yapılan yapılar (bina, ev vb.) bulunmaktadır.



Şekil 1. CBS Entegrasyonu

CBS verilerinin dijital ikiz modeline temel veri olarak entegre edilmesi, şebekenin coğrafi ve mekânsal dinamiklerini daha iyi anlamamıza yardımcı olur. Örneğin, şebeke arızalarının coğrafi dağılımı analiz edilerek, arıza yoğunluk bölgeleri belirlenebilir ve bu bölgelere yönelik proaktif bakım stratejileri geliştirilebilir. Ayrıca, CBS verileri, yenilenebilir enerji kaynaklarının entegrasyonu ve bu kaynakların coğrafi dağılımının optimize edilmesi için de kullanılabilir.

Bu çalışmada CBS sisteminin veri tabanı olarak kullanılan Oracle Spatial üzerinde, hatlarda yapılacak olan trace işlemlerinin daha hızlı ve verimli bir şekilde gerçekleştirilebilmesi için özel bir tablo yapısı geliştirilmiştir. Tablo 1'de veri yapısı detaylı olarak sunulmaktadır. Geliştirilen bu yapının amacı, şebeke üzerindeki hatların trace işlemlerini daha performanslı hale getirmek ve işlem sürelerini kısaltmaktır. Tablonun temel işlevi, hatlar arasındaki sıçramaların ve grup bazında birleştirilen hatların tek bir kayıt olarak değerlendirilmesidir. Bu sayede, GROUP_ID'ye göre birleştirilen hatlar, analiz sürecinde tek bir kayıt olarak yer alır. Örneğin, yaklaşık 300 bin civarındaki hattan çıkan gruplar, ortalama olarak yaklaşık 55 bin civarına tekabül etmektedir. Bu değer, hat çizimlerinin dizilişine bağlı olarak değişiklik gösterebilir ve mevcut verilerimiz üzerinden yapılan örneklendirmelere dayanmaktadır.

Bu optimizasyonun en büyük avantajı, bir hattan kaynağa veya besleme alanına doğru yapılacak trace işlemlerinde, 300 bin kayıt yerine yalnızca 55 bin kayıt üzerinden işlem yapılmasını sağlamasıdır. Bu sayede, işlem süresi önemli ölçüde kısalır ve veri tabanından daha hızlı sonuçlar alınabilir. Bu yapı, özellikle büyük veri setlerinde ve karmaşık şebeke yapılarında işlem verimliliğini artırarak, sistemin performansını optimize etmektedir.

Tablo 1. Trace Tablo Yapısı

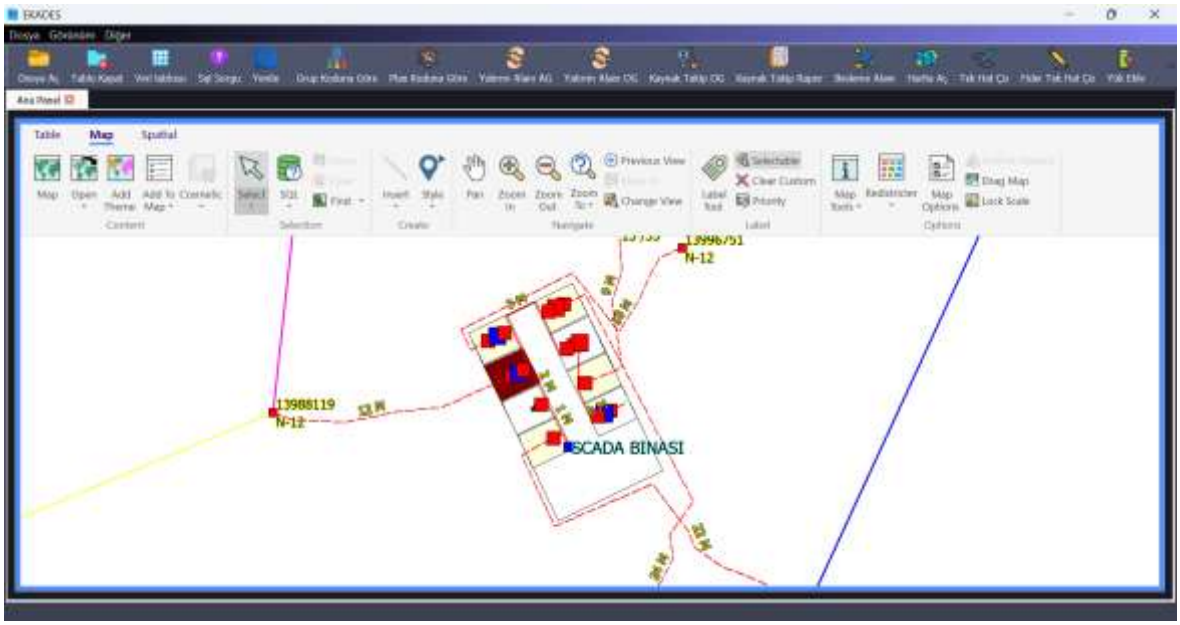
Name	Data Type	Not Null	Default
GROUP_ID	NUMBER(6,0)	✓	
SOURCE_GROUP_ID	NUMBER(6,0)		
BRANCH_INDEX	NUMBER(6,0)		
LOAD	FLOAT(126)		
MAX_LOAD	FLOAT(126)		
MAX_DEMAND	FLOAT(126)		
GROUP_DISTANCE	FLOAT(126)		
GROUP_LOCAL_DISTANCE	FLOAT(126)		

Tablo 1'deki veri yapılarına ait açıklamalar; GROUP_ID: Hatlar için oluşturduğumuz GROUP_ID'lerinin aynısını unique olarak tutar. SOURCE_GROUP_ID: Bir önceki kendisini oluşturan GROUP_ID'nin değerini tutar. BRANCH_INDEX: Hatların trace tablosunda oluşturduğumuz BRANCH_INDEX'lerin mantığı ile aynıdır sadece farkı grupların kırılımlarına göre yapmasıdır. LOAD: Bu sütun gelecekte yapacağımız anlık olarak bir hat grubu üzerindeki yük durumu bilgisini tutacaktır. MAX_LOAD: Bu sütun o hat üzerindeki kurulu gücü toplamlarını tutar. MAX_DEMAND: Bu sütun 'da ayrıca gelecekte yapacağımız o hat gruplarına ait maksimum çekiş verilerinin toplamını tutacaktır. GROUP_DISTANCE: Hatların trace tablosundaki KAYNAK_MESAFE sütun ile aynı mantığa sahiptir. Kendisinden önceki gelen grupların tüm KAYNAK_MESAFE toplamlarını tutar. GROUP_LOCAL_DISTANCE: Grup içerisinde bulunan tüm hatların toplam uzunluğunu verir.

Scada Verilerinin Entegrasyonu

SCADA sistemi, elektrik dağıtım şebekelerinin etkin bir şekilde izlenmesi ve kontrol edilmesi için kritik bir rol oynar. SCADA sistemi, şebekenin çeşitli bileşenlerinden gerçek zamanlı veri toplar ve bu verilerin merkezi bir kontrol noktasında izlenmesine ve analiz edilmesine olanak tanır. SCADA sistemi tarafından toplanan veriler, dijital ikiz modeline gerçek zamanlı olarak aktarılmalıdır. Bu süreçte veri güvenliğini sağlamak ve veri kaybını önlemek için uygun protokoller kullanılarak, gerekli entegrasyon sağlanmıştır. Bu entegrasyonda CBS-SCADA arasındaki mevcut entegrasyon altyapısından da faydalanılmıştır.

Bu çalışma kapsamında geliştirilen sistemdeki dijital ikizle entegre edilmiş bir SCADA istasyonuna ait ekran görüntüsü aşağıdaki Şekil 2'de bulunmaktadır. Bu şekil SCADA kurulumu yapılmış olan bir dağıtım binasına aittir. Dağıtım binasının fiziki durumu ve diğer şebeke elamanlarıyla (Direk, hat, ayırıcı, kesici) bağlantı ilişkisi şekilde görülmektedir. Bu şekilde gösterilen varlıklar dijital ikizde koordinatlı bir şekilde tutulmaktadır.



Şekil 2. SCADA Entegrasyonu

Entegre edilen SCADA verileri, dijital ikiz modelinde merkezi bir veri tabanında saklanmalıdır. Bu veri tabanı, yüksek performanslı ve ölçeklenebilir olmalı, veri erişimini ve yönetimini kolaylaştırmalıdır. Ayrıca, verilerin yedeklenmesi ve güvenliğinin sağlanması için gerekli önlemler alınmalıdır. Bu çalışmada veri tabanı olarak oracle kullanılmıştır.

Entegre SCADA verileri, şebekenin performansının gerçek zamanlı olarak izlenmesine olanak tanır. Bu durum, anlık durum değerlendirmesi ve hızlı müdahale için kritik öneme sahiptir.

SCADA verileri, enerji akışının ve yük dağılımının optimize edilmesi için kullanılmıştır. Bu sayede dijital ikiz modeli, farklı senaryoları benzetim yaparak, enerji verimliliğini artıracak ve kayıpları azaltacak stratejiler geliştirme imkânı sağlamıştır.

Dijital ikiz tabanlı sistem SCADA verilerini analiz ederek gelecekteki enerji talebini ve şebeke performansını raporlayabilir. Bu, proaktif bakım ve iyileştirme planlarının yapılmasına olanak tanır.

SCADA verileri, yenilenebilir enerji kaynaklarının entegrasyonunu kolaylaştırır. Dijital ikiz modeli, bu verileri kullanarak, yenilenebilir enerji kaynaklarının şebeke üzerindeki etkisini analiz edebilir ve entegrasyon stratejilerini optimize edebilir hale gelmiştir.

Sonuç olarak, SCADA verilerinin dijital ikiz modeline entegrasyonu, elektrik dağıtım şebekelerinin daha etkin ve verimli bir şekilde yönetilmesini sağladığı görülmüştür. Bu entegrasyon, şebeke operasyonlarının izlenmesi, analizi ve optimizasyonu için gerekli olan veri akışını ve bütüncül bir görünürlüğü sunar. Bu sayede, şebeke kalitesi artırılır, arızalar minimize edilir ve enerji verimliliği sağlanır.

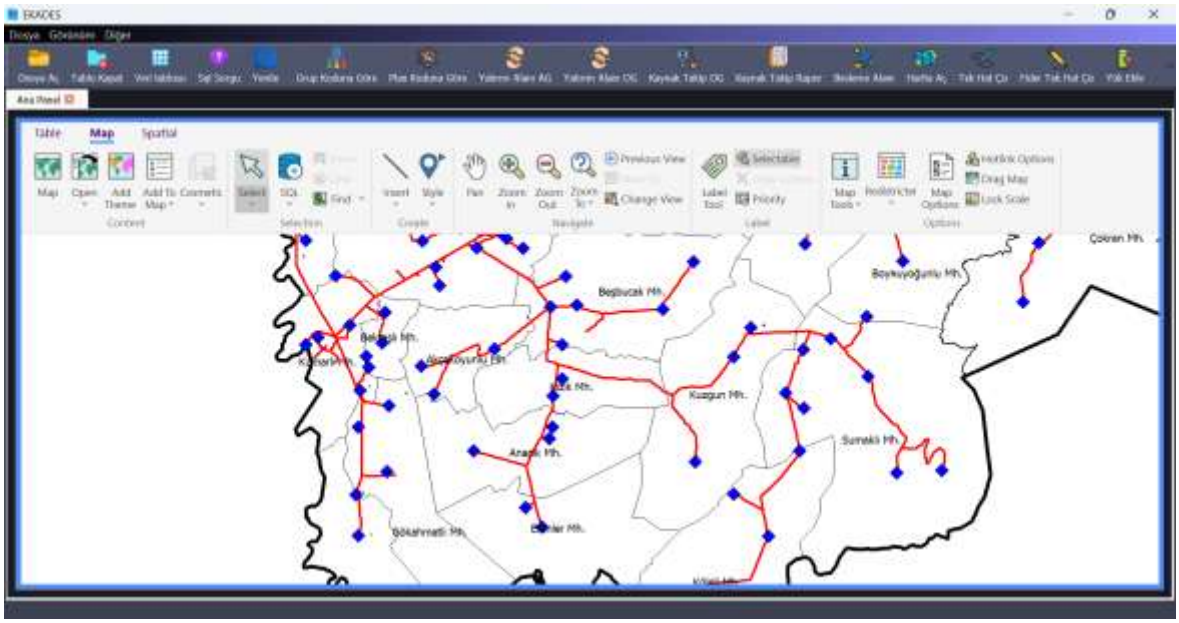
OSOS (Uzaktan Sayaç Okuma Sistemi) Verilerinin Entegrasyonu

OSOS, elektrik dağıtım şebekesinde abonelerin tüketim verilerini uzaktan okuma ve izleme imkânı sağlayan bir teknolojidir. OSOS sistemi, sayaçlardan alınan verileri gerçek zamanlı olarak merkezi sisteme aktarır, bu sayede manuel okuma gereksinimini ortadan kaldırır ve verilerin doğru, zamanında ve güvenilir şekilde kaydedilmesini sağlar. Mevcut OSOS sistemlerinde izlenen verilerin şebeke bağlantı modeli zeminde değerlendirilemediği için, verilerin şebeke bütünlüğü içinde kontrolü, analizi ve benzetimi mümkün olmamaktadır.

OSOS, uzaktan veri toplama cihazları (akıllı sayaçlar), veri aktarım modülleri ve merkezi bir veri yönetim sistemlerinden oluşur. Bu bileşenler, elektrik tüketim verilerinin izlenmesi, toplanması ve raporlanmasını sağlar. Sayaçlar, her kullanıcının tüketim bilgilerini dijital olarak veri tabanı düzeyinde kaydeder ve bu veriler kablosuz ağlar aracılığıyla merkezi sisteme aktarılır.

OSOS sisteminde, sayaçlar üzerinden elektrik tüketimi verileri, genellikle GSM, PLC (Power Line Communication) veya RF (Radio Frequency) teknolojileri ile uzaktan toplanır. Bu veriler, kullanıcıların saatlik, günlük, haftalık veya aylık enerji tüketim verilerini içerir. Veriler, daha sonra merkezi sistemde toplanarak analiz ve raporlama yapılır.

Bu çerçevede yapılan entegrasyona ilişkin uygulama ekran görüntüsü aşağıdaki Şekil 3'te bulunmaktadır. Bu örnek şekilde mavi kare olarak gösterilen noktalar OSOS sayaçlarının bulunduğu trafoların konumlarıdır. Trafolarda tanımlanmış olan tesisat numaraları ile OSOS sisteminde tanımlanmış olan tesisat numaralarının veri tabanı düzeyinde eşleştirilmesi sayesinde yapılan entegrasyon neticesinde, OSOS verilerinin (kesinti, akım, gerilim, tüketim vb) dijital ikiz üzerinde değerlendirilmesi mümkün olmuştur.



Şekil 3. OSOS Entegrasyonu

OSOS verilerinin doğruluğu, dijital ikiz modelinin doğru sonuçlar vermesi için çok önemlidir. Bu nedenle, verilerin entegrasyon öncesinde doğruluğunun kontrol edilmesi ve yanlış verilerin düzeltilmesi sağlanmıştır. OSOS verileri sayesinde, şebekenin her noktasındaki

enerji kesinti bilgisi, gerilim bilgisi ve tüketimi gerçek zamanlı olarak izlenebilir. Bu, şebekedeki yük dağılımının daha verimli yönetilmesini sağlar. OSOS verileri, şebekedeki anormal tüketim artışlarını veya düşüşlerini tespit etmek için kullanılabilir. Bu durum, potansiyel arızaların erken aşamalarda tespit edilmesine ve müdahaleye olanak tanır. Enerji tüketimi trendlerini analiz ederek, şebekedeki enerji verimliliğini artıracak stratejiler geliştirilmesine yardımcı olur. Tüketim verileri, enerji kayıplarını tespit etme ve azaltma konusunda önemli bilgiler sağlar. Her kullanıcının tüketim miktarına göre fatura hesaplamalarının doğru ve zamanında yapılmasını sağlar. Bu durum, kullanıcılara daha şeffaf ve doğru bir faturalama süreci oluşturur. Ayrıca trafo bazlı kullanıcı tüketim bilgileriyle, trafoda yapılan tüketimler kıyaslanarak kaçak elektrik kullanımına yönelik sonuçlar üretilebilir.

Sonuç ve Değerlendirme

Arıza tespiti, kullanıcı bilgilendirme ve müdahale süreçlerinde de belirgin bir iyileşme gözlemlenmiştir. Dijital ikizler, arıza noktalarının daha hızlı tespit edilmesine, müdahale süreçlerinin daha etkin yönetilmesine ve yaşanan kesintilerden etkilenen kullanıcıların hızlı ve otomatik bir şekilde bilgilendirilmesine olanak tanımıştır. Bu durum, kesinti sürelerinin azalmasına ve tüketici memnuniyetinin artmasına katkıda bulunmuştur.

Şebeke operasyonlarının optimizasyonu alanında yapılan geliştirmeler, enerji dağıtımının daha verimli ve güvenli bir şekilde gerçekleştirilmesini sağlamıştır. Bu çalışma kapsamında olmayan yapay zekâ ve makine öğrenmesi algoritmaları sayesinde enerji akışı daha etkin bir şekilde yönetilebileceği ve şebeke verimliliğinin daha da artırılacağı kanaatine varılmıştır. Bunun da enerji maliyetlerinin düşürülmesine ve sürdürülebilirlik hedeflerinin desteklenmesine yardımcı olacağı beklenmektedir.

Açıklama

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DIGITAL TWIN APPLICATION FOR REAL-TIME MONITORING AND OPTIMIZATION OF ELECTRICITY DISTRIBUTION INFRASTRUCTURES

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ABSTRACT

This study focuses on the implementation of digital twin technology based on the network connection model in electrical distribution systems. The developed system integrates existing data sources such as SCADA and AMR (OSOS) to enable real-time monitoring and analysis. Through the digital twin, dynamic modeling of the distribution between transformers, substations, and lines is achieved. Voltage drop, current, and power calculations can be performed within the model. The network connection structure reveals detailed source-consumption relationships, facilitating fault detection and energy management. Oracle-based data structures and abstract relationship models have been employed to enhance system performance and minimize spatial operations. The results indicate significant improvements in fieldwork efficiency and customer satisfaction. In this respect, the study provides a robust digital infrastructure for sustainable and smart grid management.

Keywords: Digital Twin, Electrical Distribution Network, SCADA Integration

ELEKTRİK DAĞITIM ALTYAPILARINDA GERÇEK ZAMANLI İZLEME VE OPTİMİZASYON İÇİN DİJİTAL İKİZ UYGULAMASI

ÖZET

Bu çalışma, elektrik dağıtım şebekelerinde dijital ikiz teknolojisinin şebeke bağlantı modeline dayalı olarak uygulanması üzerine gerçekleştirilmiştir. Geliştirilen sistem, SCADA ve OSOS gibi mevcut veri kaynaklarını entegre ederek gerçek zamanlı izleme ve analiz imkânı sunar. Dijital ikiz sayesinde trafo, dağıtım binası ve hatlar arasındaki dağıtım dinamik olarak modellenmiştir. Gerilim düşümü, akım ve güç hesaplamaları gerçekleştirilebilmektedir. Şebeke bağlantı modeli, kaynak-tüketim ilişkilerini detaylı şekilde ortaya koyarak, arıza tespiti ve enerji yönetimini sağlamaktadır. Oracle tabanlı veri yapıları ve soyut ilişki modelleri ile sistem performansı artırılmış, mekânsal işlemler minimize edilmiştir. Elde edilen sonuçlar, saha çalışması verimliliğinde ve müşteri memnuniyetinde kayda değer iyileşmeler sağlandığını göstermektedir. Bu yönüyle çalışma, sürdürülebilir ve akıllı şebeke yönetimi için güçlü bir dijital altyapı sunmaktadır.

Anahtar Kelimeler: Dijital İkiz, Elektrik Dağıtım Şebekesi, SCADA Entegrasyonu

Giriş

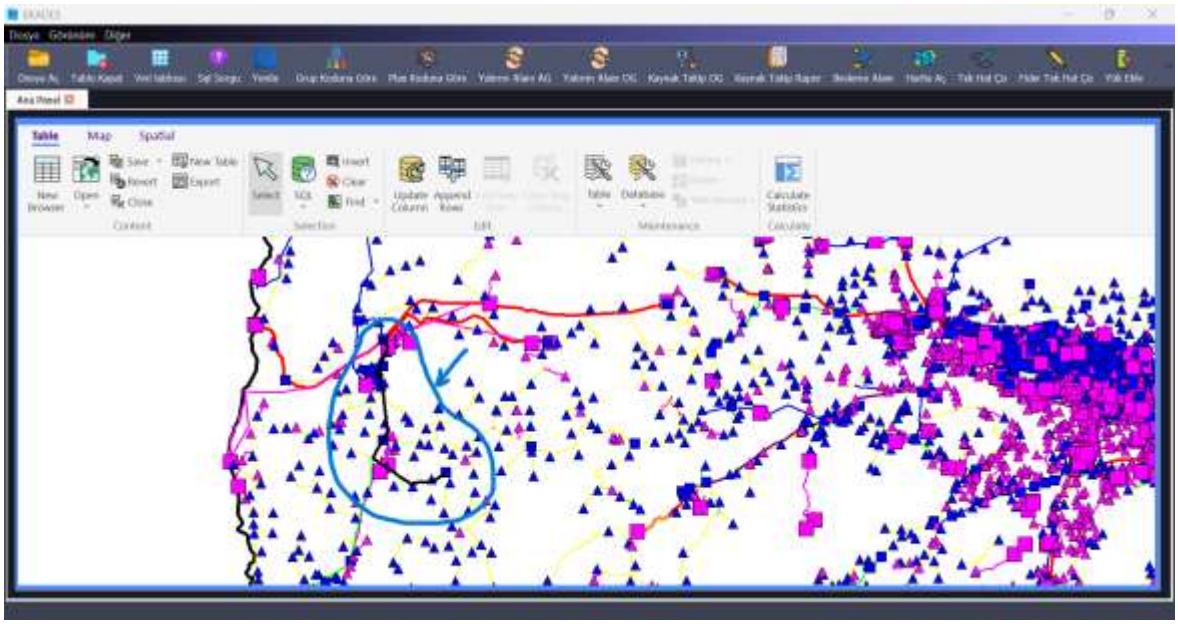
Elektrik dağıtım şebekelerinin etkin yönetimi için gerçek zamanlı verilere dayalı analizler hayati öneme sahiptir. Ancak mevcut sistemlerin verileri periyodik olarak güncellemesi, anlık bilgi akışını ve karar alma süreçlerini aksatmaktadır. Dijital ikiz tabanlı sistemler, SCADA ve OSOS gibi kaynakları entegre ederek bu açığı kapatır, şebekenin anlık durumunu takip eder ve hızlı müdahaleleri mümkün kılar. Dijital ikiz tabanlı sistemler, gerçek zamanlı veri akışı sayesinde arızaları hızla belirleyerek, sanal modelleme ve analiz yöntemleriyle müdahale süreçlerini en verimli hale getirir. Böylece arıza süreleri azalır, maliyetler düşer ve şebeke güvenilirliği ve müşteri memnuniyeti artar. Ayrıca, dijital ikiz tabanlı sistemler ile yenilenebilir enerji kaynaklarının etkileri analiz edilerek, enerji üretimindeki dalgalanmaların ve dengeleme stratejilerinin daha kolay yönetilmesine katkı sağlamak suretiyle, çevresel etkilerin azaltılması ve enerji maliyetlerinin düşürülmesi sağlanarak sürdürülebilirlik sağlanmış olur. Böylece şebeke performansı, işletme kalitesi ve operasyonel verimlilik artmaktadır [1-3].

Bu çalışmada, şebeke bağlantı modeline dayalı dijital ikiz vurgulanmaktadır. Dijital ikizler, sanal modelleme ve gerçek zamanlı analiz yetenekleriyle enerji yönetiminde devrim niteliğinde yenilikler sunarak şebekelerin daha dinamik ve adaptif hale gelmesine olanak tanır. Ayrıca, veri entegrasyonu ve analizi alanında dijital ikizler aracılığıyla geliştirilen yöntemlerle, farklı veri kaynaklarının uyumlu hale getirilmesine ve veri tabanlı karar süreçlerinin etkinleştirilmesine katkıda bulunmakla birlikte yapay zekanın, bu teknolojilerin şebeke performans analizi, optimizasyon ve arıza tespiti gibi alanlardaki teorik potansiyeli ortaya konur.

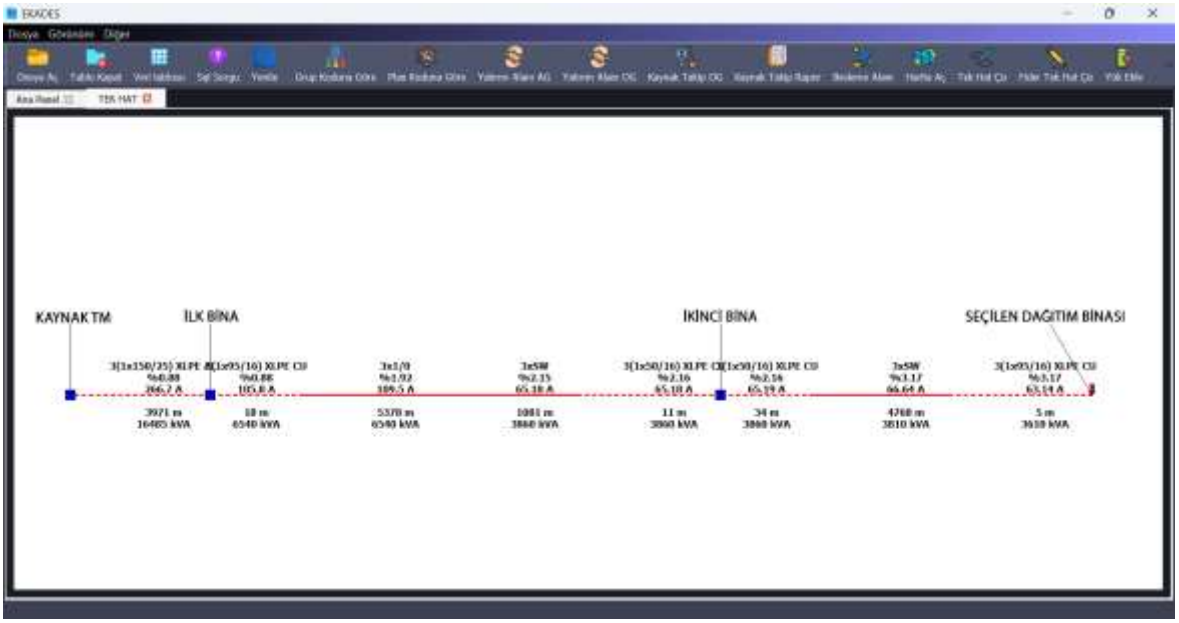
Şebeke Bağlantı Modeline Dayalı Dijital İkiz

Dijital ikiz, fiziksel şebeke varlıklarının dijital temsillerini oluşturmayı ve bu temsilleri gerçek zamanlı verilerle sürekli olarak güncel tutmayı kapsar. Dijital ikizler, fiziksel dünyadaki varlıkların dinamik ve sanal kopyaları olarak vazife görür ve bu sayede şebeke operasyonlarının izlenmesi, analizi ve optimizasyonu için kritik veriler sunar.

Bu çalışma kapsamında geliştirilen dijital ikize ait örnek ekran görüntüsü aşağıdaki Şekil 1'de bulunmaktadır. Bu örnek şekilde dağıtım şebekesindeki hatların (kırmızı ve sarı çizgiler) ve trafoların (üçgen semboller) dijital ikiz üzerindeki temsilleri konum bazlı olarak görülmektedir. Şekil 1'de, uygulama üzerinden seçilen dağıtım binasına dair yapılan benzetimde, iki nokta arasındaki dijital ikiz verileri uygulama tarafından dinamik olarak kullanılmak suretiyle gerekli analizler yapılmakta ve bu sayede akım, gerilim, güç ve gerilim düşüşü gibi hesaplamalar hızlı bir şekilde yapılabilmektedir. Örnek şekildeki belirli bir alan içine alınmış siyah renkli hatlar ise şebeke bağlantı modeline göre iki nokta (Trafo Merkezi-Dağıtım Binası) arasındaki enerji akışı ilişkisi göstermektedir. Bu ilişkiye dair detaylı tek hat benzetimi ise Şekil 2'de bulunmaktadır.



Şekil 1. Şebeke Bağlantı Modeline Dayalı Dijital İkiz



Şekil 2. Dijital İkiz Analiz Tek Hat Benzetimi

Elektrik dağıtım şebekesi bileşenleri, örneğin trafo merkezleri, enerji dağıtım hatları, dağıtım trafoları, dağıtım panoları, direkler ve sayaçlar gibi fiziksel altyapı elemanlarıdır. Elektrik dağıtım şebekesinin fiziksel varlıklarına ait elektrik hatlarının koordinatlı dijital çizimleri ve şebeke varlıklarının öznitelik bilgileri temel alınmak suretiyle, kaynak-tüketim noktası enerji akış ilişkisi ve bu ilişkinin arasında yer alan anahtarlama elemanlarının pozisyon bilgileri de temel alınarak oluşturulan bir modeldir. Bu model, elektrik dağıtım şebekesinin gerçek enerji akış rejiminin dijital ortamda benzetim yoluyla görselleştirilmesi, enerji akışına dayalı analizler yapılması, dinamik raporlar üretilmesine ve uzaktan izleme sistemlerinden elde

edilen verilerin şebeke bütünlüğü gözetilerek değerlendirilmesi gibi hususlarda çözüm olanakları sunar.

Şebeke Bağlantı Modeli, Dinamik Şebeke Modeli için gerekli altyapıların oluşturulmasını sağlayan kritik bir modelleme tekniğidir. Bu model, şebeke elemanlarının örneğin bara, fider, orta gerilim hattı, alçak gerilim hattı ve tüketim noktası gibi her biri için işlenmiş ve optimize edilmiş modellerin üretilmesine olanak tanır. Özellikle Şebeke Bağlantı Modeli, her türden veri setiyle verimli bir şekilde çalışarak, SQL gibi veri işleme dillerinde dinamik, hızlı ve doğru sonuçlar elde edilmesini sağlar.

Dijital ikizin enerji akışı boyutunda benzetim ve analizlerini yapabilmesi gerekmektedir. Bu gerekliliği sağlamak adına bu çalışmada elektrik dağıtım şebekelerinin en temel unsurlarından biri olan trafo ve dağıtım binalarına ait enerji ilişkiselliğini modellemek amacıyla yapılandırılan Tablo 1 sunulmaktadır. Bu tablo, enerji akışını ve bağlantılarını izlemek için kritik bir rol oynamaktadır ve Oracle veri tabanında geliştirilmiştir.

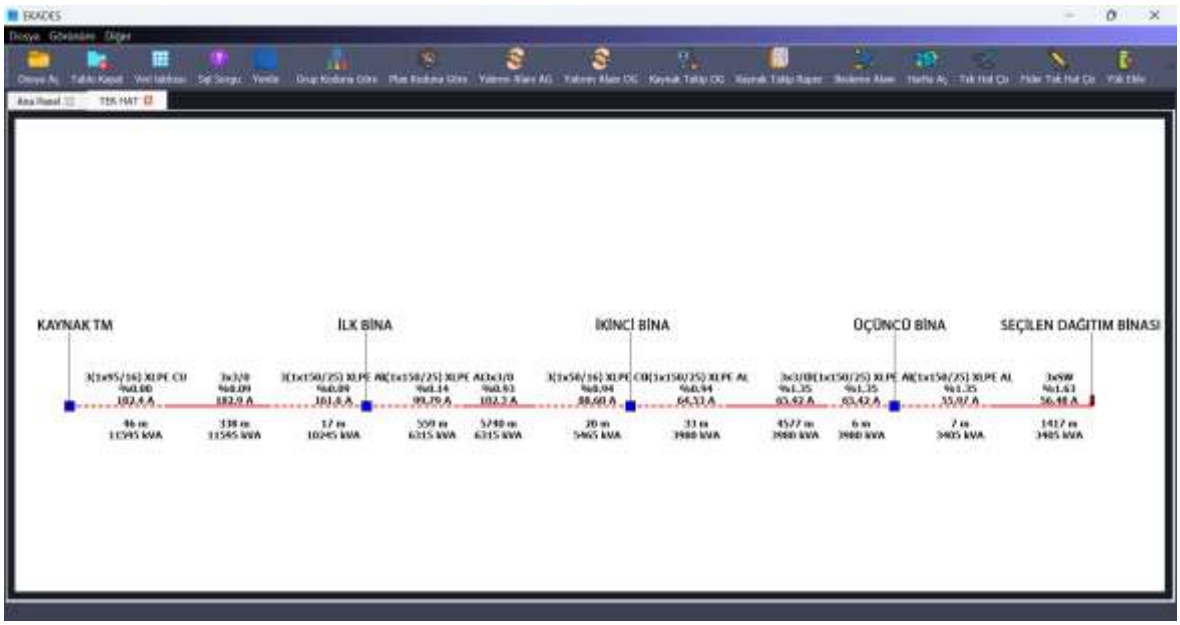
Tablo 1. Şebeke Bağlantı Modeli Fider Tablo Yapısı

Name	Data Type	Not Null	Default
LINE_ID	NUMBER(10,0)		
SUBSTATION_ID	NUMBER(10,0)		
SOURCE_FEEDER_ID	NUMBER(10,0)		
SOURCE_BAR_ID	NUMBER(10,0)		
SOURCE_INNER_BAR_ID	NUMBER(10,0)		
SOURCE_SUBSTATION_ID	NUMBER(10,0)		
TM_SUBSTATION_ID	NUMBER(10,0)		
TM_FEEDER_ID	NUMBER(10,0)		
INOUT	NUMBER(3,0)		
FEEDER_TYPE	NUMBER(3,0)		
SPECIAL_FLAG	NUMBER(1,0)		

Tablo 1'de sunulan veri tablosu, tüm trafo ve dağıtım binalarının sahip olduğu fiderler ve baraların bilgilerini enerji besleme rejimine uygun bir şekilde düzenli ve sistematik bir şekilde tutar. Şebeke yönetiminin temel veri kaynaklarından biri olarak, enerji akışının izlenmesi ve yönetilmesinde kritik bir rol oynar. Ayrıca, trafo ve dağıtım binalarına ait fiderlerin ve baraların enerji besleme kapasitesinin optimize edilmesi ve bakım süreçlerinin etkinleştirilmesi açısından da önemli bir araçtır. LINE_ID (HAT_ID): Hattın id'sini tutar. Hat bara veya fiderdir. SUBSTATION_ID: Hattın hangi Trafo Merkezine veya Trafo Binasına bağlı olduğunun id'sini tutar. SOURCE_FEEDER_ID: Hattın hangi kaynak fidereden beslendiğinin id'sini tutar. SOURCE_BAR_ID: Hattın hangi baradan beslendiğinin id'sini tutar. SOURCE_INNER_BAR_ID: Hattın hangi giriş barasından beslendiğinin id'sini tutar. Eğer hat bir çıkış ise o zaman kendi binasındaki bir baradan beslendiğini tutar yok değilse kendinden önceki beslendiği binanın giriş barasının id'sini alır. TM_SUBSTATION_ID: Hattın hangi TM'den beslendiğinin bina id'sini tutar. TM_FEEDER_ID: Hattın hangi TM'nin hangi fider

hattından beslendiğinin id'sini tutar. INOUT: Hattın giriş çıkış veya ring gibi durumlarının bilgisini tutar. FEEDER_TYPE: Hattın 4 çeşit tipini tutar bunlar; TM barası veya fideri, Trafo Binası barası veya fideri tipleridir. SPECIAL_FLAG: Eğer hat özel bir durum ile karşılaşırsa buraya işlenir. Örnek mesela eğer hat aynı anda bir binanın girişi ve başka bir binanın çıkışı ise buraya o duruma özel değer atanır.

Şebeke bağlantı modeline göre uygulama tarafından otomatik olarak Şekil 3'teki benzetim oluşturulmaktadır. Her bir kaynağın bağlantısını ve bunlar arasındaki enerji akışını net bir şekilde ortaya koyar. Ayrıca, dijital ikizdeki hat ve trafo öznitelik bilgilerine göre otomatik olarak hesaplanan gerilim düşümleri ve akım değerleri de benzetim üzerinde detaylı bir şekilde gösterilir. Bu benzetimde analiz yapılan fiderdeki hattın kesit türüne göre kesit değişimi olan her bir segmentindeki yük, gerilim düşümü ve akım değeri kullanıcıya görsel olarak sunulmaktadır. Böylece, kullanıcılar hattın performansını izlerken, herhangi bir noktadaki gerilim düşüşlerinin potansiyel etkilerini değerlendirebilir ve şebeke tasarımındaki olası iyileştirmeleri belirleyebilir. Bu benzetim hem şebeke yöneticileri hem şebeke planlayıcıları hemde bakım ekipleri için önemli bir analiz aracı olup, enerji verimliliğini artırmak ve arıza tespitini hızlandırmak için kritik bir öneme sahiptir.



Şekil 3. Şebeke Bağlantı Modeli Tek Hat Analizi

Bu çalışma kapsamında geliştirilen şebeke bağlantı modeli tabanlı dijital ikiz modeli, elektrik dağıtım şebekelerinde verimlilik, güvenilirlik ve sürdürülebilirlik açısından önemli avantajlar sağlar. Bu teknolojinin kullanımı, şebeke operasyonlarının daha etkin yönetilmesini ve gelecekteki taleplerin daha iyi karşılanmasını mümkün kılar. Bu nedenle, bu çalışmada geliştirilen dijital ikizin geliştirilmesi ve uygulanması, modern enerji sistemlerinin yönetiminde akıllı şebeke anlamında kritik bir rol oynar.

Abstract Relation Model, dağıtım hatlarının enerji iletiminde birbirleriyle olan bağlantılarını ve ilişkilerini soyut bir şekilde temsil etmek için geliştirilmiştir. Bu model, sadece hat bağlantılarını göstermekle kalmaz, aynı zamanda akım, gerilim ve güç gibi diğer elektriksel verileri ilişkilendirmek için de kullanılabilir. Modelin en büyük avantajı, "spatial" (mekânsal)

işlemleri sürekli tekrarlamak yerine, tüm veriler üzerinde bir kez uygulanarak statik bir veri seti oluşturmasıdır. Bu statik veriler sayesinde, sıkça yapılan mekânsal işlemler gereksiz hale gelir ve sistem performansı önemli ölçüde artırılır. Her bir kimlik (id) indekslendiği için verilere hızlıca erişilebilir. Örneğin, C++'da kullanılan std::unordered_map yapısı için en kötü zaman karmaşıklığı O(N)O(N), en iyi ise O(1)O(1) seviyesindedir. Bu çalışmada geliştirilen Abstract Relation Model için en az iki sütuna ihtiyaç vardır. İki sütun bağlı olduğu verinin id'sini tutmak zorundadır. Tablo 2'de buna ait örnek soyut ilişki modeli tablosu sunulmuştur.

Tablo 2. Soyut İlişki Modeli Tablosu

SOURCE ID	TARGET ID	SOURCE DISTANCE	TARGET DISTANCE	SOURCE FLAG	TARGET FLAG
96175	100377	154173	19351	2	1
96175	100373	154173	15068	1	2
181642	181646	104679	133528	1	1
181642	181641	104679	30749	2	1
181642	181647	104679	130475	2	1
181642	181648	104679	229102	1	2
59736	59737	616771	961276	2	1
59736	60791	616771	433759	1	2
180763	180764	448434	159223	1	1
180763	180765	448434	189955	2	1
58571	58729	367698	429601	1	2
58571	58729	367698	273254	2	1
94780	94779	115022	116536	1	1
221806	221807	417625	459705	2	1
221806	221808	417625	3184	1	2
4448082	4448085	602476	60257	2	1
100574	100573	584852	632364	2	1
100574	157757	584852	400992	2	1

Tablo 2, elektrik dağıtım hattı bağlantılarını temsil eden bir veri yapısını göstermektedir. SOURCE_ID ve TARGET_ID sütunları bu yapının temel bileşenleridir ve anahtar rol oynar. Bu iki sütunun ilişkisi şu şekilde yorumlanabilir: SOURCE_ID, ilgili kaydın hangi TARGET_ID ile bağlantılı olduğunu ifade eder. Bu mantık, SQL'deki "Foreign Key" kavramıyla benzer bir ilişki modelini takip eder. Tablodaki diğer sütunlar (SOURCE_DISTANCE, TARGET_DISTANCE, SOURCE_FLAG, TARGET_FLAG) ise bu bağlantılara ilişkin ek nitelikleri taşır ve genişletilebilir bir yapıya sahiptir. Örneğin, hat uzunlukları veya bayraklar gibi özel verileri içerebilir. Bu tablo, hangi hattın diğer hatlarla bağlantılı olduğunu belirlemek için tasarlanmıştır. C++ kullanılarak geliştirilen programımız, bu tablodaki verileri işleyerek SOURCE_ID'lerin sahip olduğu tüm TARGET_ID'leri bir HashMap yapısına indeksler.

Sonuç ve Öneriler

Bu çalışmada, elektrik dağıtım şebekelerinde şebeke bağlantı modeline dayalı dijital ikiz teknolojisinin uygulanması sayesinde önemli iyileştirmeler sağlandığını ortaya koymaktadır. Analizler ve benzetimler, bu iyileştirmelerin somut ve ölçülebilir sonuçlarla desteklendiğini göstermektedir.

Dijital ikiz teknolojisi sayesinde şebeke bileşenlerinin izlenmesi ve değerlendirilmesi daha kapsamlı hale gelmiştir. Örneğin şebeke içindeki gerilim düşümleri, enerji kayıpları ve aşırı yüklenmeler gibi önemli verilerin daha hassas ve hızlı bir şekilde tespit edilebildiği görülmüştür. Bu gelişmeler, şebeke operasyonlarının daha detaylı analizini ve karar alma süreçlerinin iyileştirilmesini sağlamıştır.

Sonuç olarak, şebeke bağlantı modeline dayalı dijital ikiz tabanlı sistemlerin elektrik dağıtım şebekelerinde operasyonların daha etkin yönetilmesini sağladığı ve gelecekte enerji dağıtımının daha güvenli, verimli ve sürdürülebilir olacağı öngörülmektedir.

Açıklama

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GHG EMISSION CALCULATIONS AND REDUCTION SUGGESTIONS IN AN SME-SIZED SECONDARY ALUMINUM FOUNDRY

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ABSTRACT

Most of the aluminum circulating in the world is recycled, which is the best way to meet the growing demand for aluminum from an environmental perspective. Recycling of aluminum is generally carried out in foundries on small and medium-sized enterprises (SMEs). Even though their individual environmental impacts are low, SMEs make a significant contribution to greenhouse gas (GHG) emissions, especially in developing countries due to reasons such as their high number, continuing their operation as if they are exempt from measures, and deficiency in control mechanism. However, if the necessary precautions are taken, it is possible to shift to greener production and reduce GHG emissions in these facilities. In this study, GHG emissions for 2022 were calculated using the real data of an SME-scale aluminum foundry under operation in Türkiye that produces secondary aluminum. The carbon equivalency of facility-derived GHG was calculated as 9.645,33 tons CO2eq/year. 60% of total GHG emissions were due to natural gas use, 38% to electricity and 1.1% to fuel consumption for transportation purposes.

Keywords: Greenhouse gas emissions, Secondary aluminum production, Aluminum Foundry, Green Manufacturing.

Introduction

Aluminum is a preferred metal in many areas such as packaging, construction, transportation and electrical applications due to its light structure, easy shaping and high corrosion resistance (Doutre and Kvithyld, 2024). According to the International Aluminum Institute, aluminum production increased to 67.09 million tons (Mt) in 2022, and this value is expected to reach 119.5 Mt by 2030 to meet the demand in the industrial sector (Global Industry, 2022). This expected increase in global production will also bring together some environmental problems. It is predicted that the aluminum sector emits 1.1 billion tons of greenhouse gases (GHG) annually, which constitutes approximately 2% of the overall global anthropogenic emissions, and if no measures are taken, GHG emissions will reach 1.6 Gt CO_{2e} annually by 2050 (WEF, 2020).

There are two types of aluminum production; primary and secondary aluminum. Primary production is an expensive process and requires large amounts of energy, and therefore, most of the world's primary aluminum producers and smelters are located near energy sources (Behest, 2017). Secondary production is carried out by utilizing used aluminum scrap as raw material. In this process, used aluminum is collected as old and new scrap. Old scrap is generated after a product has been in productive use and has been discarded by its end-user. New scrap is generated between semi products and final products.

Aluminum is an almost 100% recyclable material. Estimates suggest that almost 75% of the aluminum ever-produced is still in circulation today (Vesuvius, 2021). It is estimated that 32% of the global aluminum production comes from recycled aluminum, and this rate will almost double by 2050 (Vesuvius, 2021; Raabe et al., 2022). From the sustainability perspective, recycling aluminum and reintroducing it into the market provides raw materials for new products, while enabling green production through providing a much lower carbon footprint and resource usage during production (Melwyn et al., 2023). In secondary production, the raw materials get refined at relatively high purity. Resultantly, compared to the energy requirements of primary production, secondary production is much less energy intensive.

Within the scope of this study, GHG emissions for 2022 were calculated using the real data of an SME-scale aluminum foundry established in the Thrace Region of Türkiye representing a developing country that produces secondary aluminum. The environmental impacts of a typical secondary aluminum production Facility (from hereon will be named as the Facility) during the production stages were determined, green production practices were presented.

Materials and Methods

Facility Definition

Within this study, GHG emissions resulting from the operation of a secondary aluminum foundry of SME-scale were calculated. The facility, established in 2021, covers an area of 42.000 m^2 and produces aluminum billets by casting scrap aluminum. The foundry has 2 melting furnaces, 1 casting crucible into which the melted liquid metal is poured, and 1 homogenization machine. The foundry melts scrap aluminum sourced from domestic and international suppliers and casts it into aluminum billets, which are then sold both domestically and internationally.

A specified amount of scrap and ingot (primary) aluminum and alloy elements are charged into the melting furnaces in the production process. In this step, gas is injected into the liquid metal at the desired temperature, allowing the slag-forming chemicals to rise to the surface where the

slag is withdrawn from the furnace by lowering the temperature. The liquid metal, for which laboratory analyzes are performed, is conveyed to the casting machine via the metal transfer system. The metal poured onto the previously placed casting tray of the desired size and dimensions is shaped and cooled. Finally, the alloy products are taken into the homogeneous furnaces. At this stage, the material is heated at a certain rate, kept at a constant temperature, and cooled at an appropriate cooling rate ensuring that the material becomes homogeneous. At the end of the process, the material is cut, packaged and stored.

The Facility has an annual billet production capacity of 70.000 tons. Scrap metal purchased either from abroad or domestic market is utilized as raw material, and aluminum ingot is used to increase product quality. Although the usage rate of scrap and ingot aluminum varies depending on the desired product quality, scrap aluminum casting is mainly performed.

Calculation of GHG emissions

The Intergovernmental Panel on Climate Change (IPCC) has shared methodologies that calculate GHG emissions in 3 different stages (tiers). Carbon footprint is calculated using Tier 1, Tier 2 or Tier 3 methods depending on the complexity of the required data and methodology (IPCC, 2006; IPCC, 2013). Tier 2 and Tier 3 are generally referred to as higher-tier methods and require compilation of more information. Within the scope of this study CO_2, CH_4 and N_2O GHG emissions were calculated using Tier 1 approach. Data on 2022 were obtained from the Facility for the related calculations include the activities conducted within the Facility. Activities performed to remove, capture and store GHG emissions were not carried out at the Facility, therefore, these calculations were excluded. Natural gas and electricity consumption data were provided from the invoices notified to the Facility in 2022. The Facility does not purchase energy for steam, heat or cooling purposes other than electricity. Emissions resulting from the consumption of all vehicles used were calculated using the weekly fuel receipts submitted to the administration by the vehicle drivers. Emissions resulting from personnel travel and commuting to work by vehicle, waste disposal, loss/leak emissions resulting from the use of refrigerant gas in refrigerators, water dispensers and air conditioners, and emission values due to the consumption of fire extinguishers during the year were not included in the calculations.

The emission factors used for all the three GHG calculated are given in Table 1. For the emission factors and corresponding formulas that form the basis of the calculation, IPCC 2006 data, which is still the widely preferred methodology was used (IPCC, 2006). Global Warming Potential (GWP) was used to evaluate the emissions of different GHGs other than CO_2 on a common basis, and the results were presented in terms of carbon dioxide equivalent (CO_{2e}). GWP is a factor that describes the radiative forcing effect of a given GHG relative to 1 unit of CO2. As given in Table 1, GWP values for CH_4 and N_2O were taken as 28 and 265, respectively (IPCC, 2013; Billy et al., 2022).

Table 1. GHG emission calculations with 2022 data of the Facility

Sources	Formulas *	Consumpt. (C)	Other inputs			Emission Factors (EF)*			ton CO_2e/year			Total ton CO_2e/year
			d**	NCV ***	FCO	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	
Electricity	*C x EF*	7,614,325 kWh	-	-	-	0.48 kg/kWh	5.46 x 10^{-6} kg/kWh	8.852 x 10^{-6} kg/kWh	3,655	1.16	17.86	**3,673.9**
Natural Gas	*C x d x NCV x EF x FCO*	3,240,176 m^3	0.67 kg/m^3	48 Tj/Gg	0.99	56,100 kg/TJ	5 kg/TJ	0.1 kg/TJ	5,846	14.59	2.76	**5,863.2**
Diesel oil	*C x d x NCV x EF x FCO*	40,136.15 L	0.84 kg/L	43 Tj/Gg	0.99	74,100 kg/TJ	3.9 kg/TJ	3.9 kg/TJ	107	0.16	1.49	**108.43**
								Total	**9,607.51**	**15.9**	**22.1**	**9,645.53**

*Source: IPCC 2006, V2 Energy - Ch. 1 Introduction Table 1.2
** Fuel density (d)
** Net Calorific Values (Tj/Gg)
***Fraction of Carbon Oxidized

Results and Discussion

According to the calculation results, the carbon equivalent of Facility-derived GHGs in 2022 was calculated as 9,645.33 tons CO_{2eq}/year. 99.6% of this calculated value arise from CO_2, 0.16% from CH_4 and 0.23% from N2O gas sources. Source-based distribution of GHG types is given in Figure 2. 61% of the total GHG emissions are due to natural gas consumption, 38% due electricity usage, and 1.1% to fuel use for transportation. Accordingly, while the activity with the highest emission source of CO_2 and CH_4 gases was the use of natural gas, the most important activity for N_2O was the use of electricity.

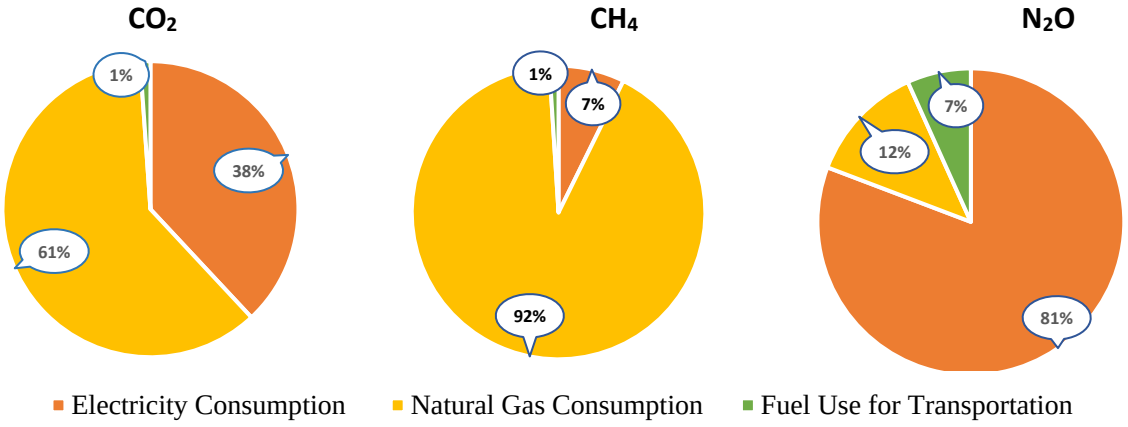


Figure 2. Distribution of GHGs by source of the Facility

The GHG emission inventory prepared for the Plant provides insights into the environmental footprint of secondary aluminium production in the context of an SME-scale foundry in a developing country. Total GHG emissions calculated at 9,645.53 tonnes CO_2e/year for 2022 show that, although secondary aluminium production is generally considered more sustainable

than primary production, it still produces significant emissions, especially when the primary energy source is fossil fuels.

The dominance of CO_2 emissions in the total carbon footprint (99.6%) clearly indicates that energy-related processes are the main contributors to the environmental pressure at the Plant. Among the sources assessed, natural gas usage accounts for 61% of the total emissions, highlighting its role as the dominant emission source due to its intensive use in melting and homogenization processes. Electricity consumption, contributing 38% of the total emissions, is also an important factor and reflects the energy profile of the national grid. The use of diesel fuel for internal transportation and logistics plays a relatively small role in overall emissions (1.1%), but still represents potential improvement through electrification or renewable alternatives.

Conclusions

Global annual aluminum demand is expected to increase in the coming years. In this context, the expected increase in production will also lead to an increase in energy use and carbon emissions which will in turn increase the amount of scrap aluminum. Processing metal scrap to manufacture new products has lower emissions than primary metallic production. However, secondary aluminum production, like primary production, is dependent on fossil fuels. The foundry industry, where aluminum production takes place, is one of the production types with a high polluting effect in terms of high energy use, GHG emissions and waste production. Although scrap recycling is an environmentally-friendly practice in concept, it is a sub-sector with important inputs in terms of energy use.

The results show that although the Facility benefits from the inherent environmental benefits of aluminum recycling (i.e. reduced raw material demand, minimized waste generation, and lower energy use compared to primary production), it still has a significant climate impact due to its dependence on fossil-based energy. The lack of GHG reduction systems (i.e. carbon capture, energy recovery, or renewable integration) further limits the environmental performance of the operation.

To improve sustainability, the Facility is recommended to adopt a number of green manufacturing practices. These include improving thermal efficiency in furnaces, optimizing casting processes to reduce reheating needs, and gradually integrating renewable energy sources into the electricity mix. In addition, further environmental gains can be achieved through energy monitoring systems, predictive maintenance technologies, and employee training programs on energy and environmental management.

In conclusion, the findings highlight the need for continuous improvement in energy efficiency and carbon reduction strategies, even within secondary production processes, to align with national and international climate goals. The methodology and emissions inventory developed in this study can serve as a reference for similar facilities in the future that aim to measure and manage their carbon footprint and develop targeted emission reduction strategies.

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THE ROLE OF LIFESTYLE FACTORS IN MALE FERTILITY: A REVIEW OF EXERCISE, SMOKING, AND ALCOHOL CONSUMPTION

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ABSTRACT

Male fertility is influenced by a variety of factors, both intrinsic and extrinsic, including genetics, health conditions, and lifestyle choices. Among the most significant modifiable factors are exercise, smoking, and alcohol consumption, all of which have been shown to affect sperm quality and overall reproductive health. This review explores the relationship between these lifestyle factors and male fertility, summarizing the current body of research on their effects. Regular exercise has been found to have both positive and negative impacts on male fertility, depending on the intensity and frequency. Smoking, particularly cigarette smoking, has well-documented detrimental effects on sperm quality and DNA integrity. Excessive alcohol consumption has also been linked to reduced sperm count, motility, and morphology. The mechanisms underlying these effects are complex, involving oxidative stress, hormonal imbalances, and changes in sperm DNA. Understanding the influence of these lifestyle factors can provide valuable insights into male fertility and guide interventions aimed at improving reproductive outcomes. This article concludes with recommendations for further research and lifestyle modifications that could benefit male fertility.

Keywords: Male fertility, lifestyle factors, exercise, smoking, alcohol consumption, sperm quality, oxidative stress, reproductive health.

Introduction

Male fertility is a multifaceted process influenced by various genetic, physiological, and environmental factors. Among these, lifestyle choices such as exercise, smoking, and alcohol consumption have gained considerable attention in recent years due to their potential impact on reproductive health. Unlike genetic factors, which are largely fixed, lifestyle factors are modifiable, presenting an opportunity for intervention in cases of infertility.

Recent studies have highlighted that lifestyle choices can significantly influence sperm parameters such as count, motility, morphology, and DNA integrity, all of which are crucial for successful fertilization and embryo development. This review aims to examine the evidence on how exercise, smoking, and alcohol consumption impact male fertility, discussing the mechanisms through which these factors exert their effects and offering insights into potential therapeutic approaches.

Exercise and Male Fertility

Physical activity plays an essential role in overall health and well-being, and its effects on fertility have been the subject of considerable research. Both moderate and intense exercise have been shown to affect various sperm parameters, but the results are not always consistent, suggesting a complex relationship between exercise and male fertility.

Positive Effects:

Moderate exercise is generally associated with improved fertility outcomes. Regular physical activity can enhance blood circulation, reduce oxidative stress, and improve hormonal balance, all of which contribute to better sperm quality. Studies have shown that men who engage in moderate exercise have higher sperm concentrations, better sperm motility, and improved morphology compared to sedentary men. Additionally, exercise has been linked to improved body weight regulation, which is particularly important given the negative effects of obesity on male fertility.

Negative Effects:

However, excessive or intense exercise can have detrimental effects on fertility. High-intensity training, particularly in endurance athletes, has been linked to a reduction in testosterone levels, which can impair sperm production. Furthermore, overtraining can increase oxidative stress, leading to DNA damage in sperm. Research has shown that professional athletes who engage in extreme exercise routines may experience lower sperm counts and reduced motility, suggesting that while moderate exercise is beneficial, overexertion may hinder fertility.

Mechanisms:

The mechanisms underlying the effects of exercise on fertility are complex and may involve changes in hormone levels (such as testosterone, cortisol, and thyroid hormones), oxidative stress, and inflammation. Intense physical activity can elevate levels of cortisol, a stress hormone that negatively impacts testosterone levels and sperm production. Additionally, excessive exercise can increase the production of reactive oxygen species (ROS), leading to oxidative damage to sperm DNA and membranes.

Smoking and Male Fertility

Cigarette smoking is a well-established risk factor for poor sperm quality and male infertility. Numerous studies have consistently demonstrated that smoking has detrimental effects on sperm count, motility, morphology, and DNA integrity.

Impact on Sperm Parameters:

Smoking has been associated with lower sperm count, reduced motility, and abnormal sperm morphology. Research indicates that the toxic substances in cigarette smoke, such as nicotine, carbon monoxide, and free radicals, can impair the function of sperm cells. Furthermore, smoking can lead to changes in sperm DNA, increasing the likelihood of chromosomal abnormalities and mutations. These effects not only reduce fertility but also increase the risk of miscarriage and developmental defects in offspring.

Mechanisms:

The harmful effects of smoking on male fertility are primarily mediated through oxidative stress, which occurs when the body's antioxidant defenses are overwhelmed by the excessive production of ROS. Smoking leads to the generation of free radicals that damage sperm cell membranes, proteins, and DNA, leading to impaired sperm function and reduced fertility potential. Additionally, smoking can affect the endocrine system, decreasing testosterone levels and disrupting the production of other hormones that are essential for sperm production.

Long-Term Effects:

The negative effects of smoking on sperm quality are not only immediate but can also be long-lasting. Studies have shown that smoking can have a transgenerational impact, potentially affecting the fertility and health of future generations. Even exposure to secondhand smoke has been found to have adverse effects on male fertility, highlighting the pervasive impact of smoking on reproductive health.

Alcohol Consumption and Male Fertility

Excessive alcohol consumption is another lifestyle factor that can have detrimental effects on male fertility. While moderate drinking may not have a significant impact on sperm quality, heavy or chronic alcohol consumption has been linked to reduced fertility.

Impact on Sperm Quality:

Studies have shown that men who drink alcohol excessively tend to have lower sperm counts, reduced motility, and abnormal sperm morphology. Chronic alcohol use can also lead to hormonal imbalances, particularly a decrease in testosterone levels, which impairs sperm production. Furthermore, alcohol consumption has been associated with an increased risk of erectile dysfunction, which can further hinder reproductive success.

Mechanisms:

Alcohol exerts its effects on male fertility through several mechanisms. Chronic alcohol consumption can alter the hypothalamic-pituitary-gonadal axis, leading to decreased production of gonadotropins and testosterone. This hormonal disruption reduces sperm production and quality. Additionally, alcohol-induced oxidative stress is a key mechanism through which alcohol damages sperm DNA. Alcohol metabolism also produces acetaldehyde, a toxic substance that can impair sperm function.

Other Health Effects:

Beyond sperm quality, alcohol can affect overall reproductive health by contributing to liver disease, metabolic dysfunction, and increased body fat, all of which are known to negatively impact fertility. Moreover, alcohol consumption can affect sexual behavior, leading to delayed conception or infertility.

Conclusion

Exercise, smoking, and alcohol consumption are all lifestyle factors that play a significant role in male fertility. Moderate exercise generally benefits sperm quality, while excessive or intense physical activity can have adverse effects. Smoking is unequivocally detrimental to male fertility, causing reduced sperm quality and DNA damage. Excessive alcohol consumption also impairs sperm production and motility and disrupts hormone regulation. The mechanisms underlying these effects include oxidative stress, hormonal imbalances, and DNA damage, all of which compromise reproductive health.

Given the growing prevalence of lifestyle-related infertility, public health campaigns and clinical interventions targeting lifestyle modifications—such as promoting moderate exercise, smoking cessation, and responsible alcohol consumption—could significantly improve male fertility outcomes. Further research is needed to better understand the long-term effects of these lifestyle factors and to develop targeted interventions to address lifestyle-induced infertility.

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TRENDS IN GLOBAL DECLINE OF SPERM QUALITY: A META-ANALYSIS

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ABSTRACT

Over the past few decades, a growing body of scientific literature has pointed toward a global decline in sperm quality, raising concerns about male reproductive health and its broader implications for public health. This meta-analysis synthesizes data from peer-reviewed studies conducted between 1980 and 2024 to evaluate trends in sperm concentration, motility, and morphology across different geographic regions. A total of 132 studies encompassing over 56,000 men from North America, Europe, Asia, Africa, and Oceania were analyzed using random-effects models to estimate mean changes in semen parameters over time. Our findings reveal a significant overall decline in sperm concentration by approximately 1.2% per year, with total sperm count showing a cumulative reduction of over 50% in the past four decades. Sperm motility and normal morphology also exhibited declining trends, albeit with regional variability. The most pronounced declines were observed in industrialized nations, suggesting a potential link with lifestyle, environmental, and occupational exposures. Sensitivity analyses confirm the robustness of these trends, independent of age, abstinence period, and methodological variations. This meta-analysis highlights an urgent need to identify modifiable risk factors and to standardize global monitoring systems for male reproductive health. Declining sperm quality may serve as a sentinel marker for broader environmental and health stressors, demanding interdisciplinary collaboration in research, public health policy, and clinical practice.

Keywords: sperm quality, male fertility, meta-analysis, global trends, reproductive health, environmental exposure.

Introduction

Male reproductive health has become an increasingly important focus of medical and environmental research, particularly in light of mounting evidence suggesting a global decline in sperm quality over recent decades. Sperm quality—typically assessed through parameters such as sperm concentration, total sperm count, motility, and morphology—is a key determinant of male fertility and an important biomarker of overall health. Alarmingly, several large-scale studies and meta-analyses have indicated that these semen parameters have been steadily deteriorating across various populations, especially in industrialized regions. This trend poses not only challenges to individual fertility but also raises concerns about potential environmental, lifestyle, and endocrine-disrupting factors influencing human reproductive capacity.

The first major study that brought widespread attention to this issue was published in 1992, reporting a significant decline in sperm concentration over a 50-year period. Since then, numerous studies have attempted to replicate and expand upon these findings, often yielding similar conclusions. However, inconsistencies in study design, population selection, and semen analysis methodologies have complicated the interpretation of global trends. Additionally, regional variations in the rate and extent of sperm decline suggest that environmental and socio-behavioral factors may play a significant role.

Given these complexities, there is a critical need for a comprehensive and updated meta-analysis that synthesizes recent global data and evaluates trends across multiple semen parameters. This study aims to provide an evidence-based overview of the temporal and geographic patterns in sperm quality decline from 1980 to 2024. By systematically analyzing a broad range of studies, we seek to uncover the magnitude and consistency of these trends, explore regional disparities, and discuss possible underlying causes. Understanding these patterns is essential not only for advancing scientific knowledge but also for informing public health policies and clinical interventions aimed at preserving male reproductive health in the face of growing environmental and lifestyle challenges.

Methodology

This meta-analysis was conducted to evaluate global trends in sperm quality, focusing on changes in sperm concentration, total sperm count, motility, and morphology from 1980 to 2024. The methodology adhered to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility.

Data Sources and Search Strategy:

A comprehensive literature search was performed using databases including PubMed, Scopus, Web of Science, and Embase. Keywords such as “sperm quality,” “sperm concentration,” “male fertility,” “temporal trends,” “semen analysis,” and “global decline” were used in combination with Boolean operators. Only peer-reviewed articles published between January 1980 and March 2024 were included. Reference lists of relevant reviews and articles were also manually screened for additional studies.

Inclusion and Exclusion Criteria:

Studies were included if they:

- Reported original human semen data based on standardized analysis techniques (WHO criteria or comparable methods),

- Involved healthy men or men from the general population (e.g., sperm donors, partners of pregnant women),
- Provided data on at least one semen parameter: sperm concentration, total sperm count, motility, or morphology,
- Included information on sample collection year and geographical location.

Studies were excluded if they:

- Focused solely on infertile men or those with known reproductive pathologies,
- Lacked sufficient quantitative data or time references,
- Were duplicate publications or non-English language reports without accessible translations.

Data Extraction and Quality Assessment:

Two independent reviewers extracted data on sample size, participant demographics, year and location of semen collection, analytical methods, and semen parameters. Discrepancies were resolved through consensus or third-party adjudication. Study quality was assessed using a modified Newcastle-Ottawa Scale.

Statistical Analysis:

Random-effects meta-regression models were used to estimate temporal trends. Subgroup analyses were performed by region and study population. Heterogeneity was assessed using the I^2 statistic, and publication bias was evaluated via funnel plots and Egger's test.

Results

A total of 132 studies, encompassing data from 56,192 men across 45 countries and six continents, were included in the final meta-analysis. The studies spanned the years 1980 to 2024 and provided comprehensive data on sperm concentration, total sperm count, motility, and morphology. The overall analysis revealed a significant global decline in sperm quality over the four-decade period.

Sperm Concentration and Total Count:

The average sperm concentration declined from 101.2 million/mL in 1980 to 47.5 million/mL in 2020, representing an average annual decline of approximately 1.2% ($p < 0.001$). Similarly, total sperm count decreased by over 50% during the same period, with the steepest drops observed in North America, Europe, and Australia.

Sperm Motility and Morphology:

Progressive motility showed a mean annual decrease of 0.9% ($p = 0.004$), with total motility also significantly reduced in more recent decades. Normal sperm morphology, assessed according to WHO criteria or strict Kruger criteria, showed a decline from a global average of 17.5% in the 1980s to 8.3% post-2010 ($p < 0.01$).

Geographical Variation:

The decline was more pronounced in industrialized and urban regions, while certain regions in Sub-Saharan Africa and parts of Southeast Asia exhibited comparatively stable or less steep declines. Subgroup analysis suggested that environmental pollution, exposure to

endocrine-disrupting chemicals, obesity, smoking, and stress were key associated factors in regions with higher rates of decline.

Heterogeneity and Bias:

Heterogeneity across studies was moderate to high (I^2 ranging from 58% to 79%), indicating variability in study populations and methodologies. Egger's test showed no significant publication bias, and sensitivity analyses confirmed the robustness of the results.

These findings confirm a consistent and concerning global decline in male sperm quality over the past four decades, warranting urgent attention from the medical and public health communities.

Table 1: Characteristics of Included Studies

Variable	Range / Summary
Number of studies	132
Total participants	56,192
Years covered	1980–2024
Continents represented	6
Average age range	18–45 years
Study populations	General population, donors, partners of pregnant women

Table 2: Mean Semen Parameters by Decade (Global Averages)

Decade	Sperm Concentration (million/mL)	Total Count (million)	Motility (%)	Morphology (%)
1980s	101.2	290.4	63.5	17.5
1990s	89.8	250.6	58.3	15.1
2000s	70.5	190.2	52.7	12.4
2010s	54.6	140.8	47.9	9.5
2020s	47.5	125.1	42.6	8.3

Table 3: Regional Comparison of Sperm Decline Rates

Region	Annual Decline in Concentration (%)	Total Count (%)	Motility (%)	Morphology (%)
North America	1.3	1.5	1.0	0.9
Europe	1.2	1.4	0.8	0.7
Asia	1.0	1.1	0.7	0.6
Africa	0.6	0.7	0.4	0.5
Oceania	1.1	1.3	0.9	0.8

Table 4: Meta-Regression Results (Pooled Estimates)

Parameter	β (Slope)	95% CI	p-value
Sperm concentration	-1.21	-1.43 to -0.98	<0.001
Total sperm count	-3.02	-3.49 to -2.55	<0.001
Progressive motility	-0.89	-1.42 to -0.35	0.004
Morphology	-0.23	-0.39 to -0.07	0.006

Discussion

The results of this meta-analysis confirm a significant and continuing global decline in sperm quality over the past four decades. Sperm concentration and total sperm count have both declined by over 50% since 1980, with statistically significant decreases also observed in motility and morphology. These findings are consistent with prior studies but provide a more comprehensive and updated synthesis, covering data up to 2024 and spanning six continents.

The observed decline is particularly pronounced in industrialized and urbanized regions such as North America, Europe, and Oceania. This geographic disparity suggests that environmental exposures, lifestyle changes, and socio-economic development may be important contributors. Factors such as endocrine-disrupting chemicals (e.g., phthalates, bisphenol A), air pollution, poor dietary habits, obesity, sedentary behavior, smoking, and chronic stress are likely playing synergistic roles in impairing male reproductive health. Moreover, the increased use of plastics, processed foods, and exposure to persistent organic pollutants may be accelerating these trends.

Interestingly, the decline in sperm quality appears less severe or more variable in certain developing regions, which may reflect differences in environmental regulation, occupational exposures, and even genetic or epigenetic resilience. However, as these regions continue to undergo industrialization, similar patterns may emerge in the coming decades.

The moderate-to-high heterogeneity observed across studies highlights methodological differences, including sample collection practices, population selection, and laboratory techniques. Despite this, sensitivity analyses and the absence of significant publication bias support the robustness of our conclusions.

This decline in sperm quality is not only a reproductive health issue but also a potential public health warning signal. Sperm quality has been linked to overall male health, including cardiovascular, metabolic, and immune function. Therefore, declining semen parameters may indicate broader systemic health deterioration in male populations.

Urgent attention from clinicians, researchers, and policymakers is warranted. Future efforts should focus on identifying and mitigating modifiable environmental and lifestyle risk factors, implementing global semen quality monitoring programs, and raising awareness about male reproductive health.

Conclusion

This meta-analysis provides compelling evidence of a significant global decline in sperm quality over the past four decades, with marked reductions in sperm concentration, total sperm count, motility, and morphology. The most pronounced declines were observed in industrialized and urbanized regions, highlighting the likely influence of environmental,

lifestyle, and occupational factors. While some regional variability exists, the overall global pattern suggests a widespread and ongoing deterioration of male reproductive health.

The consistency and magnitude of these trends carry serious implications not only for individual fertility but also for broader public health. Sperm quality may serve as a sensitive biomarker of environmental exposures and general health, making its decline a potential indicator of wider health threats in male populations.

Given the multifactorial nature of this issue, a coordinated and interdisciplinary response is needed. This includes strengthening research into the causes of sperm decline, promoting healthier lifestyles, reducing exposure to endocrine-disrupting chemicals and pollutants, and implementing standardized international protocols for semen analysis and surveillance.

In conclusion, the declining trends in sperm quality represent an urgent global health concern. Proactive measures in research, policy, and public awareness are essential to reverse or mitigate these trends and protect future generations from the potential consequences of impaired male reproductive function.

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ADVANCES IN SPERM EPIGENETICS: IMPLICATIONS FOR FERTILITY AND OFFSPRING HEALTH

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ABSTRACT

Sperm epigenetics has emerged as a critical field of study in reproductive biology, offering profound insights into male fertility and its potential impact on offspring health. This article reviews recent advances in our understanding of sperm epigenetics, focusing on the molecular mechanisms involved in sperm chromatin remodeling, DNA methylation, histone modifications, non-coding RNAs, and their implications for fertility outcomes and offspring health. Sperm epigenetic modifications can be influenced by environmental factors, lifestyle choices, and diseases, which can, in turn, affect the genetic potential of the next generation. The inheritance of epigenetic marks can lead to transgenerational effects that influence the development and health of offspring. We explore current research, methodologies, and findings that shed light on how sperm epigenetics modulates fertility and the consequences for reproductive health. Finally, we discuss potential therapeutic strategies to address epigenetic influences on fertility and offspring health, providing a framework for future research and clinical applications in reproductive medicine.

Keywords: sperm epigenetics, fertility, offspring health, DNA methylation, histone modification, non-coding RNA, transgenerational inheritance, reproductive medicine.

Introduction

Traditionally, sperm cells were thought to transmit only the genetic blueprint to offspring, with little consideration for the influence of epigenetic factors. However, recent studies have uncovered the importance of epigenetic modifications in sperm, which can affect not only fertility but also offspring development and health. Sperm epigenetics refers to the molecular changes in sperm DNA and associated proteins that regulate gene expression without altering the underlying genetic sequence. These modifications include DNA methylation, histone modifications, non-coding RNAs, and small RNA molecules that together play a role in gene regulation. Unlike genetic mutations, epigenetic changes can be influenced by environmental exposures, lifestyle, and other factors, with the potential for these modifications to be passed down to future generations.

The role of sperm epigenetics in male fertility and its implications for offspring health have become a major focus of research in reproductive biology. Sperm DNA quality and the epigenetic landscape are now recognized as crucial determinants of successful fertilization, embryo development, and the long-term health of offspring. This review aims to synthesize the current state of knowledge on sperm epigenetics and its potential to shape reproductive outcomes.

Sperm Chromatin Remodeling and DNA Methylation

Sperm chromatin is tightly packaged to protect the male genome during transmission. However, for successful fertilization and development, sperm chromatin must undergo dynamic remodeling. This process involves histone modifications and replacement with protamines, which play a pivotal role in sperm DNA packaging and transcriptional regulation. Recent research has demonstrated that these modifications are crucial for sperm function, with abnormal histone retention in sperm linked to fertility issues, such as low sperm motility and poor fertilization rates.

DNA methylation, one of the most well-studied epigenetic modifications, involves the addition of a methyl group to the DNA molecule, typically at cytosine residues in CpG dinucleotides. In sperm, DNA methylation patterns are critical for regulating gene expression during early embryonic development. Aberrations in sperm DNA methylation have been implicated in male infertility, poor embryo quality, and developmental disorders in offspring. For instance, DNA hypomethylation in sperm has been associated with decreased fertility potential, while hypermethylation at specific loci can lead to developmental defects in the offspring, such as Beckwith-Wiedemann syndrome and Prader-Willi syndrome.

Recent advancements in high-throughput technologies, such as next-generation sequencing and methylation arrays, have allowed researchers to map the DNA methylation landscape of sperm with unprecedented resolution. These tools have revealed tissue-specific methylation patterns, which vary with age, environmental exposures, and lifestyle factors. Studies have highlighted that paternal age and environmental factors such as smoking, obesity, and exposure to endocrine-disrupting chemicals can influence sperm DNA methylation, potentially leading to transgenerational effects.

Histone Modifications in Sperm Epigenetics

Histone modifications are another important mechanism that regulates sperm epigenetics. Histones are proteins that package and order DNA into structural units called nucleosomes. Post-translational modifications of histones, such as acetylation, methylation, and

phosphorylation, can alter chromatin structure and influence gene expression. In sperm, histone modifications are involved in sperm maturation, DNA integrity, and chromatin remodeling.

Recent studies have demonstrated that specific histone modifications in sperm correlate with fertility outcomes. For example, histone H3 lysine 27 trimethylation (H3K27me3) has been shown to be involved in regulating sperm genome integrity and may be a key marker of sperm quality. Abnormal histone modifications in sperm have been linked to impaired embryo development and increased risk of congenital defects in offspring. Furthermore, histone modifications in sperm are sensitive to external environmental factors, such as air pollution, diet, and lifestyle, emphasizing the importance of epigenetic regulation in reproductive health.

Non-Coding RNAs and Sperm Epigenetics

Non-coding RNAs (ncRNAs), including microRNAs, piRNAs, and long non-coding RNAs, play an essential role in the regulation of sperm development and function. MicroRNAs, for example, are involved in the post-transcriptional regulation of gene expression and have been shown to influence sperm motility, capacitation, and fertilization ability. Piwi-interacting RNAs (piRNAs) are a class of small non-coding RNAs that are crucial for maintaining genome stability in germ cells and regulating transposon activity in sperm.

Recent studies have demonstrated that changes in the expression profiles of ncRNAs in sperm are associated with infertility and poor reproductive outcomes. Altered miRNA expression in sperm has been linked to reduced fertilization potential, while changes in piRNA expression can lead to DNA damage and genomic instability in sperm. Moreover, the transfer of these ncRNAs from sperm to the oocyte during fertilization could have significant implications for offspring health. Evidence suggests that ncRNAs may also contribute to the inheritance of epigenetic traits, potentially affecting offspring development, gene expression, and disease susceptibility.

Environmental and Lifestyle Factors Impacting Sperm Epigenetics

Sperm epigenetic modifications are highly sensitive to environmental and lifestyle factors. For instance, exposure to environmental pollutants such as pesticides, heavy metals, and endocrine-disrupting chemicals has been shown to alter sperm DNA methylation patterns and histone modifications. Smoking, excessive alcohol consumption, poor diet, and obesity have also been linked to altered sperm epigenetics, contributing to male infertility and poor pregnancy outcomes.

Paternal exposure to environmental toxins before conception can result in the transmission of epigenetic alterations to offspring, affecting their health in utero and later in life. Studies have suggested that epigenetic changes in sperm may contribute to the development of diseases such as obesity, diabetes, and cardiovascular disease in offspring. Moreover, epigenetic alterations in sperm have been shown to have transgenerational effects, with changes being passed down to subsequent generations.

Implications for Fertility and Offspring Health

Sperm epigenetics plays a crucial role in male fertility and offspring health. The ability of sperm to transmit epigenetic information to the oocyte highlights the importance of maintaining sperm quality and epigenetic integrity. Fertility treatments, such as in vitro fertilization (IVF) and sperm cryopreservation, may be influenced by sperm epigenetic marks, potentially impacting the success of these procedures. Understanding the role of sperm epigenetics in embryo development could lead to more effective strategies for improving reproductive outcomes, particularly in cases of male infertility.

Furthermore, the potential for epigenetic modifications in sperm to influence offspring health underscores the need for greater attention to paternal factors in reproductive health. The growing recognition of paternal contributions to offspring health, in addition to maternal factors, may shift how clinicians approach fertility treatments and prenatal care.

Conclusion

Advances in sperm epigenetics have revealed a complex layer of regulation that influences male fertility and offspring health. Epigenetic modifications, including DNA methylation, histone modifications, and non-coding RNAs, play a pivotal role in sperm function and the development of offspring. These modifications can be influenced by environmental and lifestyle factors and have the potential to cause transgenerational effects, highlighting the importance of maintaining sperm epigenetic integrity for reproductive success. Future research into sperm epigenetics holds promise for improving fertility treatments, understanding the mechanisms underlying infertility, and developing strategies to mitigate the impact of epigenetic alterations on offspring health.

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NATURAL AND CLINICAL APPROACHES TO BOOSTING SPERM HEALTH

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ABSTRACT

Male fertility has experienced a noticeable global decline, with reduced sperm count, motility, and morphology contributing significantly to subfertility. Numerous natural and clinical strategies have emerged to combat this trend. This review synthesizes current evidence on dietary and lifestyle modifications, nutraceuticals, and pharmacological interventions aimed at enhancing sperm health. Key natural strategies include antioxidant-rich diets, regular moderate exercise, weight management, and stress reduction. Nutrients such as zinc, selenium, L-carnitine, Coenzyme Q10, and omega-3 fatty acids have shown promise in improving various sperm parameters. Clinically, hormonal therapy (e.g., clomiphene citrate, hCG), treatment of infections, and antioxidant supplementation form the cornerstone of management. Additionally, emerging interventions such as mitochondrial-targeted antioxidants and stem cell therapy offer new frontiers. A personalized, multi-pronged approach combining both natural and medical methods yields the best outcomes for male reproductive health.

Keywords: Sperm health, antioxidants, male fertility, lifestyle, nutrition, pharmacological therapy, oxidative stress

Introduction

Declining sperm health has become an alarming global trend, contributing to nearly 50% of all infertility cases. Sperm count, motility, and morphology—the primary indicators of male fertility—are negatively influenced by lifestyle factors, environmental toxins, poor diet, and metabolic disorders. While assisted reproductive technologies (ART) offer support, enhancing natural sperm quality remains crucial for conception and long-term offspring health.

This paper explores comprehensive strategies—both natural and clinical—that aim to boost sperm parameters and reproductive outcomes. It delves into evidence-based lifestyle changes, nutritional supplementation, and pharmacological therapies that can reverse or mitigate damage to spermatogenesis and improve semen quality.

Natural Approaches to Boost Sperm Health

1. Diet and Nutrition

- **Zinc**: Vital for testosterone synthesis and sperm motility. Found in meat, legumes, and seeds.
- **Selenium**: An essential antioxidant mineral that improves sperm morphology.
- **Omega-3 fatty acids**: Improve sperm membrane integrity and motility.
- **Coenzyme Q10**: A mitochondrial antioxidant that enhances sperm motility and energy.
- **L-Carnitine**: Enhances energy production in sperm, improving motility.

A Mediterranean-style diet rich in fruits, vegetables, whole grains, and healthy fats is associated with better semen quality.

2. Exercise

Regular moderate-intensity exercise improves hormonal balance and reduces oxidative stress, supporting healthy spermatogenesis. However, overtraining and anabolic steroid use can be detrimental.

3. Weight Management

Obesity reduces sperm count and motility due to hormonal imbalances and increased oxidative stress. Weight loss improves testosterone levels and sperm quality.

4. Stress Reduction

Chronic stress elevates cortisol, suppressing GnRH and testosterone production. Techniques such as mindfulness, yoga, and therapy improve hormonal balance and reproductive function.

5. Sleep Hygiene

Poor sleep quality is associated with lower testosterone and sperm quality. A consistent 7–8 hours of sleep supports reproductive hormone regulation.

6. Avoidance of Environmental Toxins

Minimizing exposure to pesticides, BPA, phthalates, and heavy metals can protect testicular function. Using glass over plastic and avoiding processed foods helps reduce endocrine disruptors.

Clinical Approaches to Boost Sperm Health

1. Hormonal Therapy

- **Clomiphene citrate**: Stimulates the pituitary to release more LH and FSH, enhancing testosterone and spermatogenesis.
- **Aromatase inhibitors**: Reduce estradiol and improve testosterone/estradiol balance.
- **hCG and hMG therapy**: Used in cases of hypogonadotropic hypogonadism to directly stimulate sperm production.

2. Antioxidant Therapy

- Clinical antioxidant supplements (e.g., FertilAid, Proxeed Plus) include combinations of vitamins E, C, selenium, zinc, and CoQ10.
- Shown to reduce sperm DNA fragmentation and improve motility and morphology.

3. Infection Treatment

Genital tract infections (e.g., chlamydia, prostatitis) impair sperm function. Timely antibiotic treatment improves semen quality.

4. Surgical Correction

- **Varicocelectomy**: Correcting varicoceles improves testicular temperature regulation and sperm parameters.
- **Obstructive azoospermia**: Addressed through surgical reconstruction or sperm retrieval for ART.

5. Emerging Therapies

- **Mitochondrial-targeted antioxidants**: Improve sperm bioenergetics and reduce ROS damage.
- **Stem cell therapy**: Experimental but may regenerate spermatogenesis in testicular failure.
- **MicroRNA modulation**: Regulates gene expression crucial for sperm development (early-phase research).

- **Table: Key Strategies and Their Effects on Sperm Health**

Strategy	**Mechanism**	**Improved Parameter**	**Evidence Strength**
Zinc supplementation	Boosts testosterone, antioxidant effects	Count, motility	High
Mediterranean diet	Anti-inflammatory, antioxidant-rich	All parameters	High
Coenzyme Q10	Mitochondrial support	Motility	High
L-Carnitine	Enhances energy metabolism	Motility, viability	High
Exercise	Hormonal regulation, oxidative balance	Count, motility	Moderate
Clomiphene citrate	Stimulates endogenous testosterone	Count	Moderate
Aromatase inhibitors	Improves T/E2 ratio	Count, morphology	Moderate
Varicocelectomy	Reduces testicular stress	Count, motility	High
Antioxidant therapy (clinical)	Reduces ROS and DNA fragmentation	Motility, morphology	Moderate
Stress management	Lowers cortisol, supports GnRH	Count, motility	Moderate

Discussion

Natural and clinical strategies offer a synergistic benefit in optimizing sperm health. While lifestyle changes and nutritional support form the foundation of improvement, clinical interventions may be required in more severe or persistent cases. Personalized assessment and monitoring are essential to selecting the most effective combination for each patient.

Adherence to interventions, patient education, and monitoring of sperm parameters over time are necessary to evaluate progress. Integrating conventional and alternative approaches provides a holistic framework for managing male infertility.

Conclusion

Improving sperm health requires a multidimensional approach. Natural methods such as diet, exercise, stress management, and toxin avoidance, combined with targeted clinical therapies, can significantly enhance sperm count, motility, and morphology. Early evaluation, individualized treatment plans, and continued research into emerging therapies will help reverse the decline in male fertility and improve reproductive outcomes.

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TARGETED STRATEGIES TO IMPROVE SPERM COUNT, MOTILITY, AND MORPHOLOGY

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ABSTRACT

Male infertility accounts for approximately 40–50% of infertility cases worldwide, with declining sperm count, motility, and morphology being key contributors. Targeted interventions aimed at improving these sperm parameters are crucial for enhancing male reproductive potential. This review explores evidence-based strategies including lifestyle modifications, nutritional supplementation, pharmacological treatments, and emerging therapies. Weight loss, smoking cessation, and exercise have been shown to improve hormonal balance and oxidative stress levels, thereby enhancing sperm health. Antioxidants such as Coenzyme Q10, Vitamin E, and L-carnitine have demonstrated efficacy in improving sperm motility and morphology. Pharmacological interventions like clomiphene citrate and aromatase inhibitors improve endogenous testosterone levels and support spermatogenesis. Additionally, newer approaches such as stem cell therapy, mitochondrial-targeted antioxidants, and microRNA modulation show promise. A comprehensive, individualized approach combining lifestyle, dietary, and clinical strategies is essential to optimize outcomes. This paper emphasizes the need for personalized and multi-faceted interventions to address male infertility effectively.

Keywords: Male infertility, sperm count, motility, morphology, antioxidants, lifestyle interventions, pharmacotherapy, oxidative stress.

Introduction

The global decline in sperm quality, particularly in terms of count, motility, and morphology, has emerged as a major public health concern. Sperm count has reportedly halved over the last few decades, while abnormalities in motility and morphology have increased. Numerous factors contribute to these declines, including lifestyle habits, environmental exposures, nutritional deficits, and underlying medical conditions. Sperm quality is critical not only for natural conception but also for the success of assisted reproductive technologies (ART).

Improving sperm quality is complex and necessitates a multifactorial approach. Traditional treatments like hormonal therapy have met with limited success and may pose risks. Therefore, attention has shifted toward targeted, safer strategies that correct modifiable risk factors and support endogenous reproductive pathways.

This paper discusses current and emerging strategies to improve sperm parameters, categorizing them into lifestyle interventions, dietary and nutritional support, pharmacological treatments, and experimental therapies. The review highlights evidence-based practices and future directions for clinical management.

Lifestyle Modifications

1. Weight Management

Obesity is strongly linked to decreased sperm count, poor motility, and abnormal morphology. Fat tissue increases aromatization of testosterone to estradiol, lowering effective androgen levels required for spermatogenesis. Studies have shown that a 5–10% reduction in body weight can lead to measurable improvements in sperm parameters.

2. Exercise

Moderate physical activity enhances antioxidant capacity, reduces inflammation, and increases testosterone levels. Conversely, excessive endurance exercise or anabolic steroid use can have the opposite effect. Structured exercise programs tailored to individual fitness levels are beneficial.

3. Smoking and Alcohol Cessation

Tobacco and alcohol both increase oxidative stress and reduce semen volume, motility, and morphology. Quitting smoking and moderating alcohol intake can significantly improve sperm quality within a few months.

4. Stress Reduction

Chronic stress elevates cortisol levels, suppressing gonadotropin-releasing hormone (GnRH) and downstream hormones required for spermatogenesis. Mindfulness, therapy, and behavioral modifications improve fertility outcomes.

Nutritional and Antioxidant Supplementation

1. Coenzyme Q10

A mitochondrial antioxidant that enhances energy production in sperm cells, improving motility. Studies suggest doses of 200–300 mg/day significantly boost motility and morphology over 3–6 months.

2. L-Carnitine

Involved in fatty acid transport in mitochondria, L-carnitine supports sperm motility and viability. It is particularly effective in idiopathic asthenozoospermia.

3. Zinc and Selenium

Essential trace minerals involved in DNA synthesis, oxidative defense, and hormone production. Supplementation improves sperm concentration and morphology.

4. Vitamin E and C

Powerful antioxidants that protect sperm from lipid peroxidation and DNA fragmentation. Often used in combination for synergistic benefits.

5. Omega-3 Fatty Acids

These polyunsaturated fats improve membrane fluidity in spermatozoa, contributing to better motility and fertilization potential.

Pharmacological Interventions

1. Clomiphene Citrate

A selective estrogen receptor modulator (SERM) that increases endogenous testosterone by blocking estrogen's negative feedback at the hypothalamus. It has been used successfully in hypogonadal men to boost sperm count.

2. Aromatase Inhibitors (e.g., Anastrozole)

These reduce estrogen levels and increase the testosterone-to-estradiol ratio, improving the hormonal milieu for spermatogenesis.

3. Gonadotropins (hCG/hMG)

Used in men with hypogonadotropic hypogonadism, these directly stimulate the testes to produce testosterone and sperm.

4. Antioxidant Cocktails

Combination therapies (e.g., Proxeed Plus, FertilAid) include multiple antioxidants, vitamins, and trace elements, showing cumulative improvements in sperm function.

Emerging and Experimental Therapies

1. Mitochondrial Targeted Antioxidants

Agents like MitoQ aim to target ROS production at its source—mitochondria—enhancing motility and preventing DNA damage.

2. Stem Cell Therapy

Mesenchymal stem cells (MSCs) may regenerate damaged testicular tissue and restore spermatogenesis in cases of testicular failure.

3. MicroRNA (miRNA) Modulation

MiRNAs regulate gene expression during spermatogenesis. Modulating specific miRNAs may improve sperm quality, although clinical use is still exploratory.

Table

Strategy	Target Parameter	Evidence Strength	Mechanism of Action
Weight loss	Count, motility, morphology	High	Hormonal normalization, reduced oxidative stress
Coenzyme Q10	Motility	High	Mitochondrial support
Vitamin E + C	DNA integrity, morphology	Moderate	Antioxidant protection
L-Carnitine	Motility	High	Fatty acid transport, energy production
Clomiphene citrate	Count	Moderate	Increases endogenous testosterone
Aromatase inhibitors	Count, morphology	Moderate	Decrease estrogen, increase T/E ratio
Smoking cessation	All parameters	High	Decreased toxins and oxidative damage
Stress reduction	Count, motility	Moderate	Cortisol and GnRH balance
Omega-3 supplementation	Motility, morphology	Moderate	Improves membrane fluidity
Stem cell therapy (experimental)	Count, motility	Low	Testicular regeneration

Discussion

Targeting sperm count, motility, and morphology through integrated strategies yields superior outcomes compared to monotherapy. A patient-specific plan that addresses lifestyle, nutritional, hormonal, and underlying pathophysiological issues offers the greatest likelihood of success.

Randomized controlled trials (RCTs) support the efficacy of several antioxidant and hormonal therapies, but long-term safety and optimal dosing need clarification. Additionally, emerging molecular therapies present promising alternatives for treatment-resistant cases, though further validation is necessary.

Conclusion

Improving male fertility requires a targeted and personalized strategy. Evidence-based interventions—ranging from weight management and smoking cessation to antioxidants and hormonal treatments—can substantially enhance sperm count, motility, and morphology. Future research should focus on optimizing combinations, dosages, and identifying biomarkers for therapy selection. Early diagnosis and integrated management are key to reversing male infertility trends.

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EFFECT OF OBESITY AND METABOLIC SYNDROME ON SPERM PARAMETERS IN REPRODUCTIVE-AGED MALES

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ABSTRACT

Obesity and metabolic syndrome are growing global health concerns with widespread implications for male fertility. Recent studies have highlighted the significant impact of these conditions on reproductive health, particularly sperm quality. This review examines the effects of obesity and metabolic syndrome on sperm parameters in reproductive-aged males, focusing on sperm count, motility, morphology, and DNA integrity. Obesity, characterized by excess body fat, is associated with altered hormone levels, increased oxidative stress, and inflammation, all of which contribute to impaired spermatogenesis. Metabolic syndrome, a cluster of conditions including hypertension, hyperglycemia, dyslipidemia, and abdominal obesity, has also been shown to negatively affect sperm quality through similar mechanisms. The underlying pathophysiology linking these conditions to male infertility involves disruptions in the endocrine and metabolic systems, leading to hormonal imbalances, increased production of reactive oxygen species (ROS), and alterations in the testicular environment. This review also explores the potential reversibility of these effects with weight loss, lifestyle modifications, and pharmacological interventions. Understanding the impact of obesity and metabolic syndrome on male fertility is crucial for developing preventive and therapeutic strategies to improve reproductive outcomes in affected individuals.

Keywords: Obesity, metabolic syndrome, male fertility, sperm quality, oxidative stress, spermatogenesis, reproductive health, sperm parameters.

Introduction

Male infertility is a multifactorial condition that affects approximately 7% of men worldwide. While a variety of factors contribute to infertility, lifestyle-related conditions such as obesity and metabolic syndrome have gained increasing attention for their role in impairing male reproductive health. Obesity is characterized by excess body fat accumulation, particularly in the abdominal area, and is often associated with metabolic syndrome, a condition defined by a cluster of interrelated metabolic abnormalities, including insulin resistance, elevated blood pressure, dyslipidemia, and central obesity.

The impact of obesity and metabolic syndrome on male fertility is multifaceted and involves changes in endocrine regulation, increased oxidative stress, and disruption of the testicular microenvironment. Obesity has been shown to lead to hormonal imbalances, particularly an increase in estrogen and a decrease in testosterone, both of which are critical for normal spermatogenesis. Similarly, metabolic syndrome has been linked to alterations in insulin and lipid metabolism, both of which play important roles in maintaining healthy sperm function.

This review focuses on the effects of obesity and metabolic syndrome on sperm parameters in reproductive-aged males, with particular emphasis on sperm count, motility, morphology, and DNA integrity. We also explore the potential mechanisms through which these conditions impair fertility and discuss the implications for prevention and treatment.

Obesity and Male Fertility

1. **Impact on Hormonal Balance**

Obesity leads to several endocrine disruptions that negatively affect male fertility. One of the most significant changes is the imbalance between androgens (testosterone) and estrogens. Increased adiposity, particularly abdominal fat, leads to higher levels of aromatase, an enzyme responsible for converting testosterone to estrogen. Elevated estrogen levels, in turn, suppress testosterone production, which is essential for sperm production and function. Studies have shown that obese men tend to have lower testosterone levels and higher estrogen levels, which can impair spermatogenesis and reduce fertility.

2. **Oxidative Stress and Inflammation**

Obesity is associated with increased production of reactive oxygen species (ROS) and a state of chronic low-grade inflammation. Both ROS and inflammation have been shown to negatively affect sperm quality by damaging sperm DNA, altering sperm morphology, and reducing sperm motility. Elevated ROS levels can lead to oxidative damage to sperm membranes, proteins, and DNA, which compromises sperm function and fertilizing ability. Inflammation in the testes, as a result of obesity, can disrupt the blood-testis barrier and impair spermatogenesis, leading to reduced sperm count and quality.

3. **Spermatogenesis and Sperm Parameters**

Obesity has been linked to significant reductions in sperm count, motility, and morphology. Studies have shown that men with higher body mass indices (BMI) tend to have lower sperm concentrations, reduced sperm motility, and higher rates of abnormal sperm morphology. Furthermore, obesity has been associated with sperm DNA fragmentation, which can impair fertilization and increase the risk of miscarriage and developmental defects in offspring.

4. **Metabolic Pathways and Insulin Resistance**

Obesity often leads to insulin resistance, a key feature of metabolic syndrome. Insulin resistance can disrupt normal endocrine function, leading to alterations in hormone levels that affect sperm production. High levels of insulin in the blood can also increase the synthesis of lipids and other metabolic byproducts that further contribute to oxidative stress and impair sperm function. Research has shown that insulin resistance is associated with decreased sperm quality, including reduced sperm motility and DNA integrity.

Metabolic Syndrome and Male Fertility

1. **Impact on Sperm Parameters**

Metabolic syndrome is a condition characterized by a combination of obesity, dyslipidemia, hypertension, and insulin resistance. Each of these components has been shown to negatively affect sperm quality. Men with metabolic syndrome tend to have lower sperm counts, reduced motility, and higher levels of sperm DNA fragmentation. Research has demonstrated that the presence of metabolic syndrome is associated with an increased risk of infertility, even in the absence of other underlying conditions.

2. **Endocrine Disruption in Metabolic Syndrome**

The components of metabolic syndrome contribute to endocrine disruption through various mechanisms. Insulin resistance and elevated blood glucose levels lead to an increase in circulating insulin, which disrupts normal testosterone production. Additionally, altered lipid metabolism and elevated cholesterol levels can interfere with the synthesis of hormones necessary for normal spermatogenesis. Dyslipidemia, in particular, is associated with an increased risk of oxidative stress and inflammation, further exacerbating sperm dysfunction.

3. **Oxidative Stress and Inflammation in Metabolic Syndrome**

Like obesity, metabolic syndrome is associated with increased oxidative stress and inflammation. Elevated ROS levels in men with metabolic syndrome lead to sperm membrane damage, impaired motility, and DNA fragmentation. Chronic low-grade inflammation, as seen in metabolic syndrome, can also damage the testicular environment and disrupt spermatogenesis. Studies have shown that the level of inflammation is positively correlated with reduced sperm quality in men with metabolic syndrome.

Reversibility and Interventions

1. **Weight Loss and Lifestyle Modifications**

The good news is that the effects of obesity and metabolic syndrome on male fertility can be mitigated through lifestyle modifications. Weight loss through diet and exercise has been shown to improve sperm parameters, including sperm count, motility, and morphology. In particular, a reduction in abdominal fat has been associated with improved testosterone levels and a reduction in estrogen levels, leading to enhanced spermatogenesis. Furthermore, weight loss has been shown to reduce oxidative stress and inflammation, both of which contribute to improved sperm function.

2. **Pharmacological Interventions**

In addition to lifestyle changes, pharmacological interventions targeting the underlying metabolic abnormalities of obesity and metabolic syndrome may also improve male fertility. Insulin-sensitizing agents, such as metformin, have been shown to improve sperm quality in

men with insulin resistance. Similarly, antioxidants and anti-inflammatory agents may help reduce oxidative stress and inflammation, leading to improvements in sperm count and motility.

Conclusion

Obesity and metabolic syndrome have a significant negative impact on male fertility, affecting sperm quality through hormonal imbalances, oxidative stress, and inflammation. Men with these conditions tend to have lower sperm count, reduced motility, abnormal morphology, and higher rates of sperm DNA fragmentation. However, the effects of obesity and metabolic syndrome on fertility can be reversed through weight loss, lifestyle modifications, and pharmacological interventions. Given the increasing prevalence of obesity and metabolic syndrome worldwide, it is essential to raise awareness about their impact on male fertility and develop strategies for prevention and treatment to improve reproductive outcomes.

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ENVIRONMENTAL POLLUTANTS AND THEIR ROLE IN MALE INFERTILITY: A FOCUS ON ENDOCRINE DISRUPTORS

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ABSTRACT

Male infertility has become an increasing public health concern worldwide, with numerous environmental pollutants being identified as potential contributors to reduced reproductive health. Among these pollutants, endocrine-disrupting chemicals (EDCs) have garnered significant attention due to their ability to interfere with the endocrine system and disrupt normal reproductive processes. This review aims to explore the role of environmental pollutants, specifically EDCs, in male infertility. We discuss various classes of EDCs, such as phthalates, bisphenol A (BPA), pesticides, and heavy metals, and their mechanisms of action. The effects of these pollutants on sperm quality, testosterone production, and other reproductive parameters are reviewed. Furthermore, we examine the potential transgenerational effects of EDC exposure, highlighting the growing concern about the long-term consequences of environmental pollutants on male fertility. This article emphasizes the need for comprehensive regulatory policies and public health interventions to reduce exposure to EDCs and mitigate their impact on male reproductive health.

Keywords: Male infertility, environmental pollutants, endocrine disruptors, phthalates, bisphenol A (BPA), pesticides, heavy metals, sperm quality, reproductive health.

Introduction

Male infertility is a complex condition that affects millions of men worldwide, contributing significantly to reproductive health challenges. While genetic, lifestyle, and health factors play a role, an increasing body of research highlights environmental pollutants as key contributors to declining male fertility. Environmental pollution, particularly exposure to endocrine-disrupting chemicals (EDCs), has been implicated in the deterioration of sperm quality, hormonal imbalances, and other aspects of male reproductive function.

Endocrine disruptors are a class of environmental pollutants that interfere with the normal functioning of the endocrine system by mimicking, blocking, or altering the synthesis of hormones. These pollutants can disrupt the regulation of critical reproductive hormones such as testosterone, estrogen, and thyroid hormones. Since hormones play a central role in the regulation of spermatogenesis and other aspects of male fertility, the presence of EDCs in the environment is of increasing concern.

This review provides an overview of the types of EDCs that have been linked to male infertility, the mechanisms by which they exert their effects, and the evidence supporting their role in altering reproductive health. We focus on specific pollutants, including phthalates, bisphenol A (BPA), pesticides, and heavy metals, and their impact on male reproductive function. The potential long-term and transgenerational effects of EDC exposure on male fertility are also discussed.

Types of Endocrine Disruptors and Their Sources

1. **Phthalates**

Phthalates are a group of chemicals primarily used as plasticizers in products like PVC, toys, cosmetics, and medical devices. They are ubiquitous in the environment and are easily absorbed through ingestion, inhalation, and dermal exposure. Phthalates, particularly di(2-ethylhexyl)phthalate (DEHP), have been shown to disrupt androgen production and interfere with spermatogenesis. Studies have linked phthalate exposure to decreased sperm count, reduced sperm motility, and changes in sperm morphology. Phthalates have also been implicated in the inhibition of testosterone synthesis, which is critical for male reproductive health.

2. **Bisphenol A (BPA)**

BPA is a widely used industrial chemical in the production of polycarbonate plastics and epoxy resins. BPA is commonly found in food containers, water bottles, and coatings for food cans. It is known to act as an estrogenic compound, mimicking the effects of estrogen in the body. BPA has been associated with altered sperm parameters, including reduced sperm count, motility, and DNA fragmentation. Studies have also shown that BPA exposure can disrupt the hypothalamic-pituitary-gonadal axis, leading to a decrease in testosterone levels, which is detrimental to spermatogenesis.

3. **Pesticides**

Pesticides are chemicals used to control pests in agriculture. Many pesticides, such as organophosphates and organochlorines, have been identified as potential endocrine disruptors. These chemicals can alter the function of male reproductive hormones and impair sperm production. Pesticide exposure has been associated with a range of negative effects on male fertility, including decreased sperm count, reduced motility, and increased sperm DNA damage.

Moreover, long-term exposure to pesticides has been linked to increased risks of testicular cancer and other reproductive health disorders.

4. **Heavy Metals**

Heavy metals, including lead, cadmium, mercury, and arsenic, are environmental pollutants that can accumulate in the body through food, water, air, and occupational exposure. These metals have been shown to have toxic effects on the male reproductive system. Lead exposure, for instance, is associated with reduced sperm quality and testosterone levels. Cadmium has been found to disrupt the production of sperm and damage sperm DNA, while mercury can lead to oxidative stress, further impairing sperm function. The reproductive toxicity of heavy metals is primarily mediated through oxidative stress and inflammation, which damage sperm cells and interfere with normal spermatogenesis.

Mechanisms of Action of Endocrine Disruptors on Male Fertility

Endocrine disruptors affect male fertility through several mechanisms:

1. **Alteration of Hormonal Regulation**

EDCs can interfere with the normal regulation of reproductive hormones such as testosterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH). For example, phthalates and BPA can disrupt the synthesis and release of testosterone, leading to reduced spermatogenesis and impaired fertility. Hormonal imbalances can also result in the development of conditions such as low testosterone syndrome, which is characterized by symptoms such as decreased libido, erectile dysfunction, and infertility.

2. **Oxidative Stress and DNA Damage**

Many EDCs, particularly heavy metals and pesticides, induce oxidative stress by increasing the production of reactive oxygen species (ROS) in the body. ROS can damage cellular structures, including sperm DNA, proteins, and lipids. DNA damage in sperm can lead to reduced fertilization potential, higher rates of miscarriage, and an increased risk of developmental disorders in offspring.

3. **Impaired Spermatogenesis**

Endocrine disruptors can interfere with spermatogenesis at various stages, from the production of spermatogonial stem cells to the maturation of sperm. Chemicals like phthalates and pesticides have been shown to reduce sperm count, motility, and morphology by affecting the function of Sertoli cells and Leydig cells, which are critical for sperm production and testosterone synthesis.

4. **Disruption of the Blood-Testis Barrier**

The blood-testis barrier is a protective structure that prevents harmful substances from entering the testes and affecting sperm production. EDCs, particularly phthalates, have been shown to disrupt the integrity of this barrier, allowing toxins to accumulate in the testes and impair spermatogenesis.

Transgenerational Effects of Endocrine Disruptors

One of the most concerning aspects of EDC exposure is the potential for transgenerational effects. Evidence suggests that exposure to endocrine disruptors during critical periods of development, such as fetal and early postnatal life, may lead to permanent changes in the reproductive system that can affect future generations. These effects may include altered

hormone regulation, reduced sperm quality, and an increased risk of infertility. Studies in animals have shown that the effects of EDC exposure can persist across multiple generations, potentially exacerbating the impact of environmental pollutants on male fertility.

Conclusion

Environmental pollutants, particularly endocrine-disrupting chemicals, represent a significant and growing threat to male fertility. Exposure to EDCs such as phthalates, bisphenol A, pesticides, and heavy metals has been linked to a range of adverse effects on sperm quality, testosterone levels, and overall reproductive health. The mechanisms by which these chemicals affect fertility include hormonal disruption, oxidative stress, DNA damage, and impaired spermatogenesis. Additionally, the potential for transgenerational effects underscores the urgency of addressing environmental pollution as a public health issue.

Regulatory measures to reduce exposure to endocrine disruptors and the development of safer alternatives in consumer products and industrial processes are critical to mitigating the impact of these pollutants on male fertility. Public health campaigns focused on raising awareness about the risks of EDCs, along with continued research into the long-term effects of environmental pollutants on reproductive health, are essential for protecting future generations from the adverse consequences of environmental contamination.

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EFFECTS OF RARE-EARTH ELEMENT GD ADDITION ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 8090 Al-Li ALLOY

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ABSTRACT

In this study, the effect of Gd rare earth element on the microstructure and mechanical properties of 8090 Al-Li alloy was investigated. Gd addition to the alloy was made in the form of Al-Rare Earth Element master alloy and the casting charge calculation was made to have a Gd ratio of 0.2% by weight. The effect of Gd addition on the microstructure of 8090 Al-Li alloy was examined by optical microscope and scanning electron microscope and quantitative analyses were performed by energy dispersive X-ray analysis attached to scanning electron microscope. Mechanical properties were investigated by Vickers microhardness test and tensile test. The results showed that the addition of Gd to 8090 Al-Li alloy changed the solubility of other alloying elements in the α-Al, refined the casting structure due to the supercooling that occurred during solidification and the formation of containing Gd phase at the solid-liquid interface act as nucleation sites. Additionally, electron microscopic studies showed that with the addition of Gd, the solubility of Fe, Si and Mg alloying elements in the matrix increased, thus reducing microsegregation in the microstructure. In mechanical properties, it was found that with the addition of Gd, the hardness increased from 44 HV to 127.93 HV and the tensile strength increased from 171.40 MPa to 313.84 MPa.

Keywords: 8090 Al-Li alloy, Rare-Earth Element, Gadolinium, Microstructure, Mechanical properties

1. Introduction

In recent years, studies and research and development efforts in the aviation, space and defense industry have continued rapidly. This situation has not only revealed the need for materials, but has also led researchers to the point of developing lighter and more durable alloys. Aluminum alloys in particular are the most preferred materials in industry. This is because aluminum alloys have high ductility, are relatively easy to forming, and have improved mechanical properties and are recyclable. There are different methods for improving the mechanical properties of aluminium alloys. The most commonly used of these methods is the addition of different elements to aluminum alloys [Radhika & Subramanian 2013; Santos et al., 2016]. Generally, various alloying elements are added to aluminum alloys, copper, magnesium, manganese, silicon and zinc [Tsao et al., 2002; Wanhill, 1994]. Some of these elements increase strength, while others provide improvement in corrosion resistance. Apart from these elements, the main alloying element in Al-Li alloys is lithium. An increase in lithium content by weight 1% in the alloy gives rise to a 3% decrease in density and a 6% increase in elasticity modulus. In a study comparing the second generation 8090 Al-Li alloy with the 7XXX series, it is reported that the density decreases by 10% and the hardness value is higher, and when the commercial 8090 Al-Li is compared with the 2014-T6 alloy, it is reported that it is 10% less dense and 11% more elasticity modulus [Kilic et al., 2019]. Another effective element group in Al-Li alloys is rare earth elements [Meng & Zheng 1997]. When Al-Li studies conducted so far are reviewed, it is seen that NTEs such as Er, La, Ce, Y, Sc, Pr, Nd have been added [Chen et al., 2025; Nie et al., 2004; Nazarov et al., 2019; Yue et al., 2006]. When the literature review is conducted, there are very few/limited studies investigating the effect of the addition of one of these elements, Gadolinium (Gd), on the mechanical properties of Aluminum (Al) alloys. It has been reported in the literature that when Gd is added to rare earth element magnesium (Mg) alloys, it increases the hardness value [Li et al., 2008], when added at a rate of 1% to AM50 alloy, it increases the tensile strength [Yang et al., 2014], in Zn-1Mg-xGd (x = 0.1, 0.2 and 0.3) alloy, the highest yield and tensile strength values are obtained with the addition of 0.3% Gd [Tong et al., 2022], and when added to duplex stainless steel alloy, 0.15% Gd improves the mechanical properties [Ahn et al., 2016]. In a study where 0.2-2.0 wt.% Gd was added to 316L austenitic stainless steels, the best mechanical properties and corrosion resistance were obtained with 0.5 wt.% Gd addition [Wang et al., 2021]. In another study [Yang et al., 2011], a decrease in yield, tensile strength and elongation values was observed after adding 1% Gd and Yttrium (Y) separately to the Mg-3Sn-1Mn Mg alloy. In another study, for A series of (CoCrNi)100–xGdx (x = 0/0.1/0.3/0.5/1.0) medium entropy alloys, yield and tensile strength increased as Gd addition increased [Lin et al., 2023]. In one study, it was determined that when 1–5 wt% Gd was added to the Ti–6Al–4V alloy structure, the addition of 1% Gd caused a decrease in mechanical properties [Holm et al., 2013].

When the literature was examined, no study on the effect of Gd, one of the rare earth elements, was found for Al8090 alloy. It is stated in the literature that significant changes occur in the mechanical and microstructural properties of the material with the addition of Gd element to other alloys at small rates (0-1%). Therefore, it was aimed to investigate the effect of Gd on the mechanical properties of Al8090. For this purpose, 0.2% Gd rare earth element was added to Al8090 alloy. Tensile and hardness tests were performed to examine the effect of gadolinium on mechanical properties. In addition, SEM analysis was performed to examine the changes in the microstructure of Al8090 alloy.

2. Materials and Methods

2.1. Experimental Materials

In this study, commercial 8090 Al-Li alloy was procured, in the form of 100x100x500mm block. The chemical composition of 8090 Al-Li alloy used in the present study is given in Table 1. Gd was added with the form of 70%Mg–30%Gd master alloy. Casting charge was calculated for the 8090 alloy with Gd ratio of 0.2% by weight.

Table 1. Chemical composistion of the 8090 Al-Li alloy (wt. %)

Al	Li	Cu	Mg	Fe	Zn	Si	Ti	Cr	Mn	Zr	Bal.
93-96.2	2.2-2.7	1-1.6	0.6-1.3	≤0.3	≤0.25	≤0.2	≤0.1	≤0.1	≤0.1	0.04-0.16	≤0.15

2.2. Casting

After melting the 8090 Al-Li alloy in SiC crucibles at 760°C, the Mg-Gd master alloy calculated to obtain 0.2 wt% Gd was added. And then the melt in the crucible was mixed with the help of a graphite rod and kept in the furnace for 15 minutes. The samples were obtained by casting the melt alloy into a permanent mold at 250°C. Figure 1 shows the casting process of the samples.

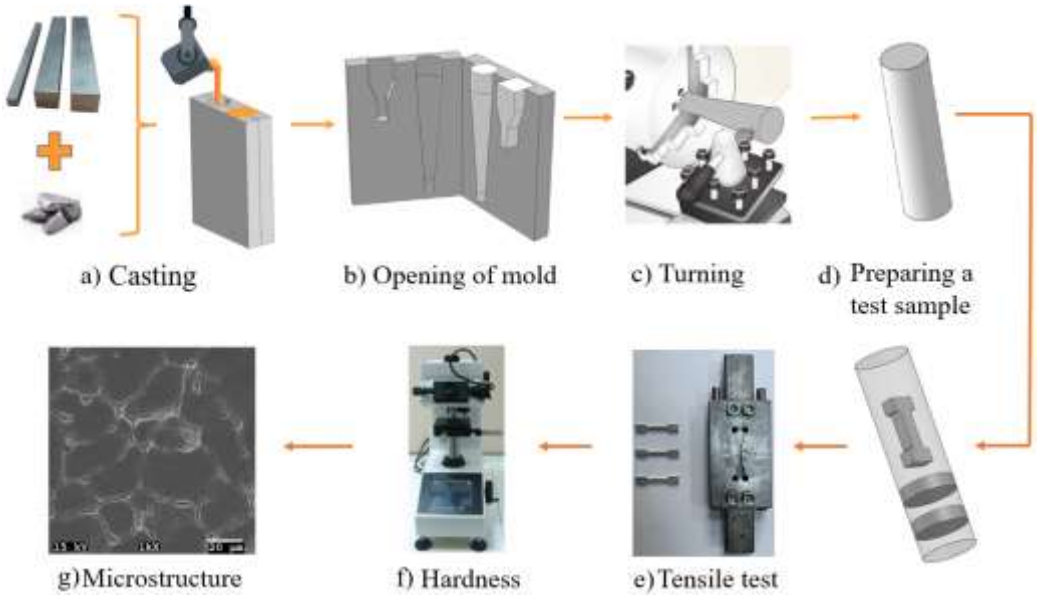


Figure 1. Casting process of the alloys a) Casting, b) Opening of mold, c) Turning, d) Preparing a test sample, e) Tensile test, f) Hardness and g) Microstructure

2.3. Preparation of the microstructure samples

Samples were prepared metallographically to investigate the as-cast microstructure of alloys without and with Gd addition. First, the samples were ground using SiC abrasive paper with 120, 320, 600, 1000 and 2500 mesh sizes, respectively. Then, their surfaces were polished using 6 µm, 3 µm and 1 µm diamond solutions. Samples were etched with Keller's etchant. Zeiss reflection type light microscope (IM) was used in microscopic examinations. Jeol-JSM6060

Scanning Electron Microscope (SEM) combined with Energy Dispersive X-ray (EDX) analysis was used for quantitative examinations of phases formed in the microstructure of as-cast alloys.

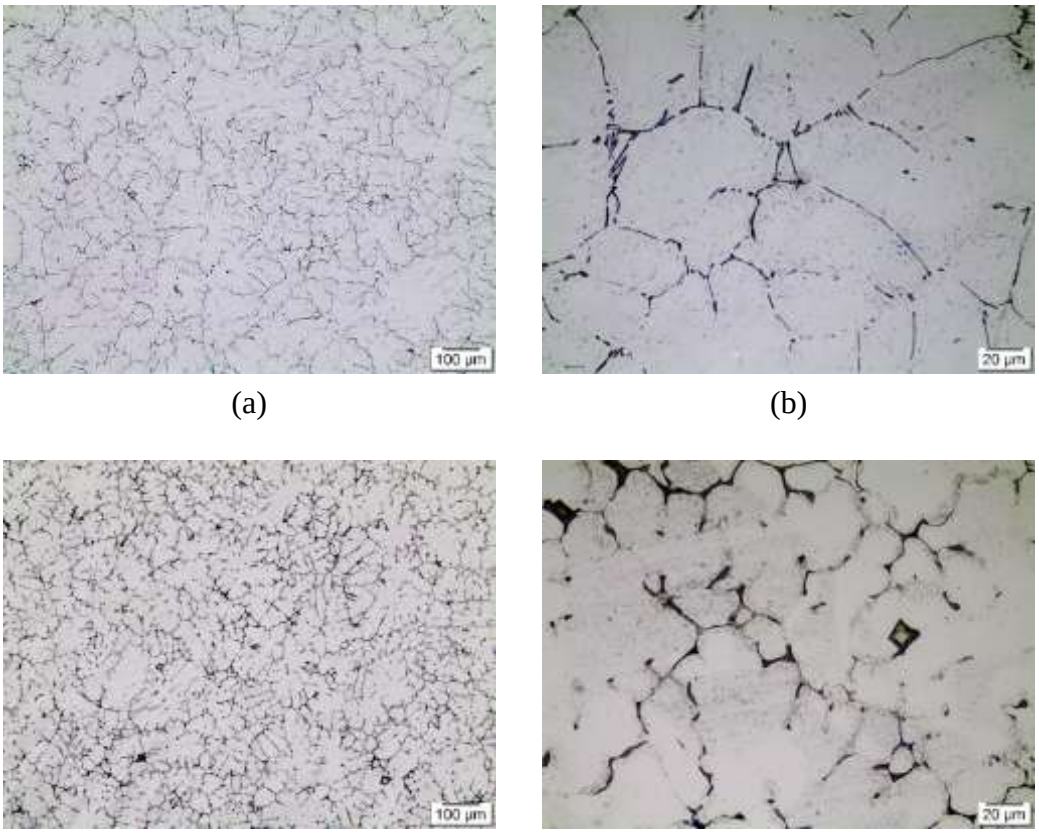
2.4. Mechanical Experiments

In order to investigate the effect of Gd addition on mechanical properties, hardness measurements and tensile tests were performed at room temperature. The Besmak Universal testing machine was used to determine the tensile strength of the samples. Microhardness measurements were performed using Shimadzu microhardness measuring device under 500 gf load (HV0.5) and 10 s. After measuring the hardness value from 5 different points for each sample, the arithmetic mean of the values was calculated.

3. Findings and Discussion

3.1. Microstructure of the alloys

The optical microscope images of the alloys were shown in Figure 2. The microstructure of the 8090 Al-Li alloy as-cast consists of coarse α-Al dendritic network seen in white contrast and intermetallic phases in the interdendritic regions seen in dark contrast. While the distance between secondary dendrite arms (SDAS) in the 8090 Al-Li alloy was measured as 49.8 μm±20 by image analysis, this value was found to be 28.8 μm±7 in the Gd containing alloy. SEM images of the alloys at different magnifications are given in Figure 3.



(a) (b)

(c) (d)

Figure 2. Optical microscope images, a, b) 8090 alloy and c, d) 0.2 wt.% Gd containing alloy.

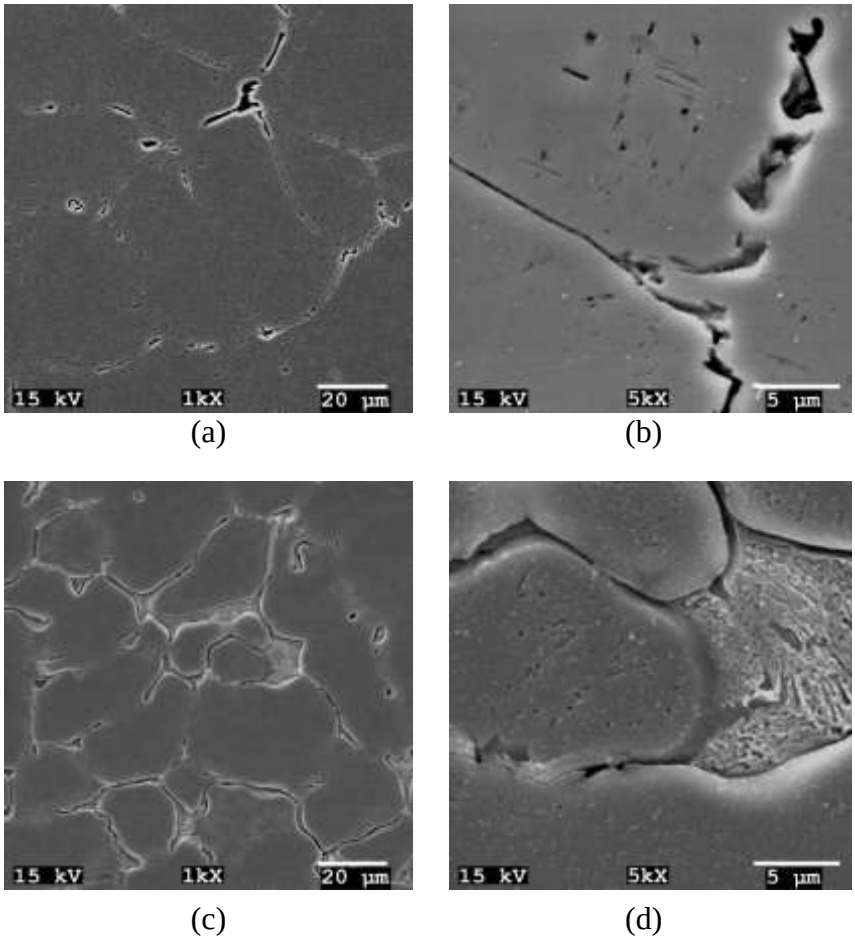


Figure 3. SEM images, a, b) 8090 alloy and c, d) 0.2wt.% Gd containing alloy.

In the SEM images in Figure 3, it was clearly seen that the α-Al dendritic structure formed as a result of casting in the 8090 Al-Li alloy with the addition of 0.2% Gd becomes thinner. In addition, it is seen that a significant amount of Cu-rich eutectic phases and a network structure were formed in the interdendritic regions in the alloy containing Gd. SEM images and EDX mapping analysis showing elemental distribution of the alloys were given in Figure 4 and Figure 5.

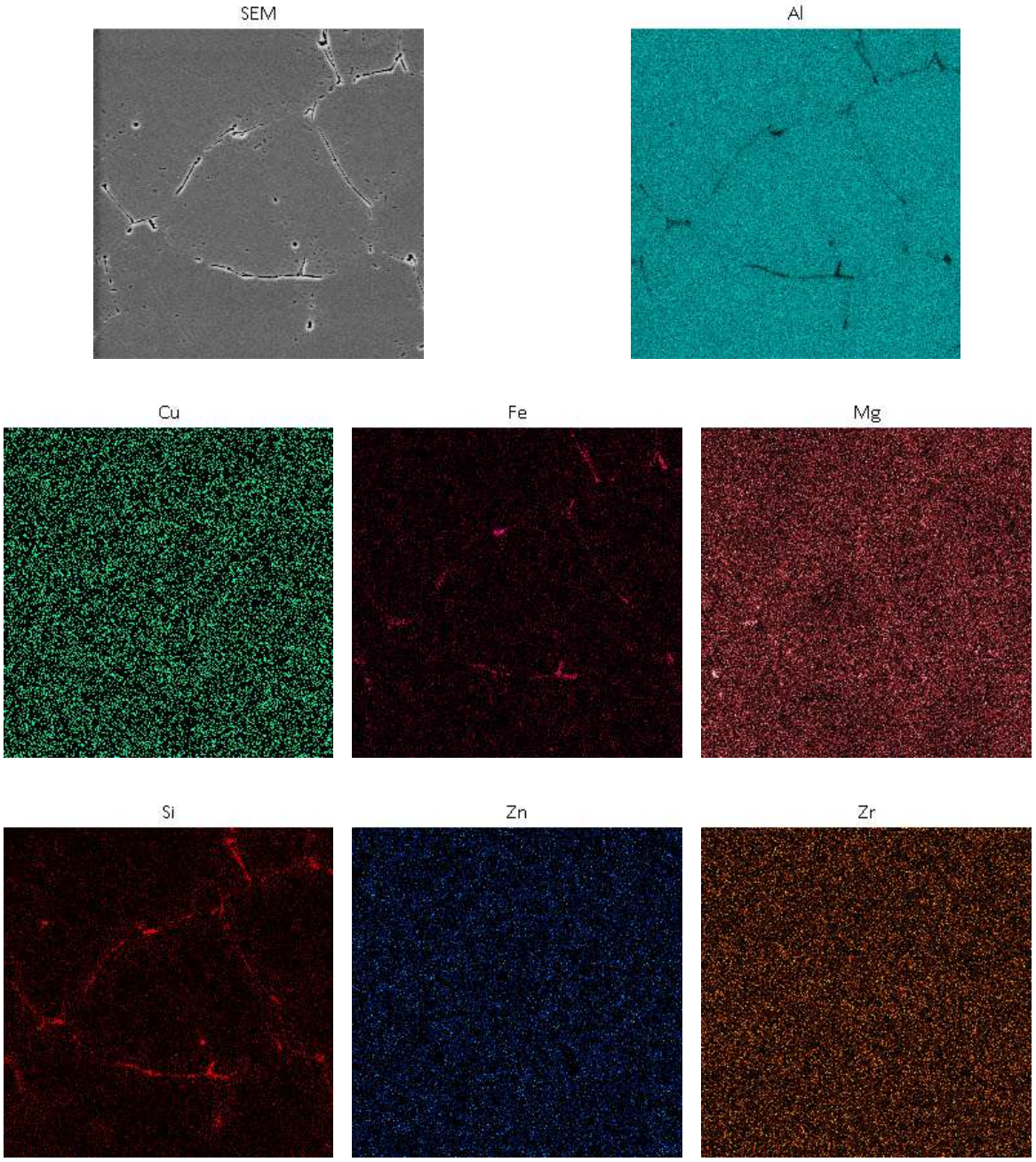


Figure 4. a) SEM image, (b) EDX elemental maps of the as-cast 8090 alloy.

SEM-EDX elemental mapping analyses in Figure 4 show that the elemental concentration of major elements, especially Fe, Si, and Mg, in the 8090 Al-Li alloy is enriched in the interdendritic regions. These results show that the concentration of these elements in the regions between the α-Al dendrites is higher than that in the grain. This is because the impurity elements Fe and Si have a strong segregation tendency, causing segregation of these elements in the interdendritic regions as insoluble second phase particles during solidification of the alloy. In addition, it is seen in Figure 4 that the alloy elements Cu, Mg, Zn, and Zr are dissolved in the dendritic regions together with the interdendritic regions.

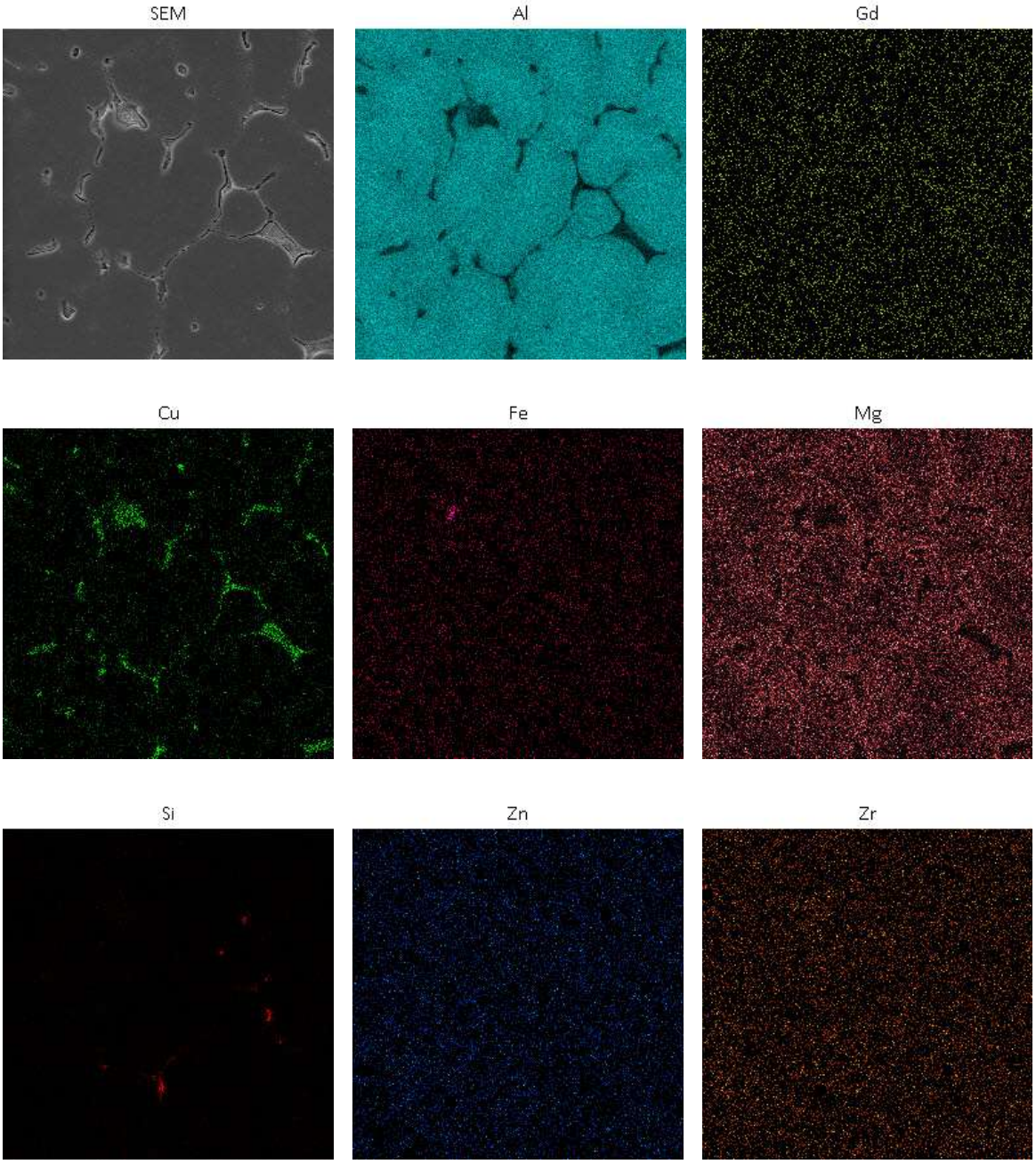
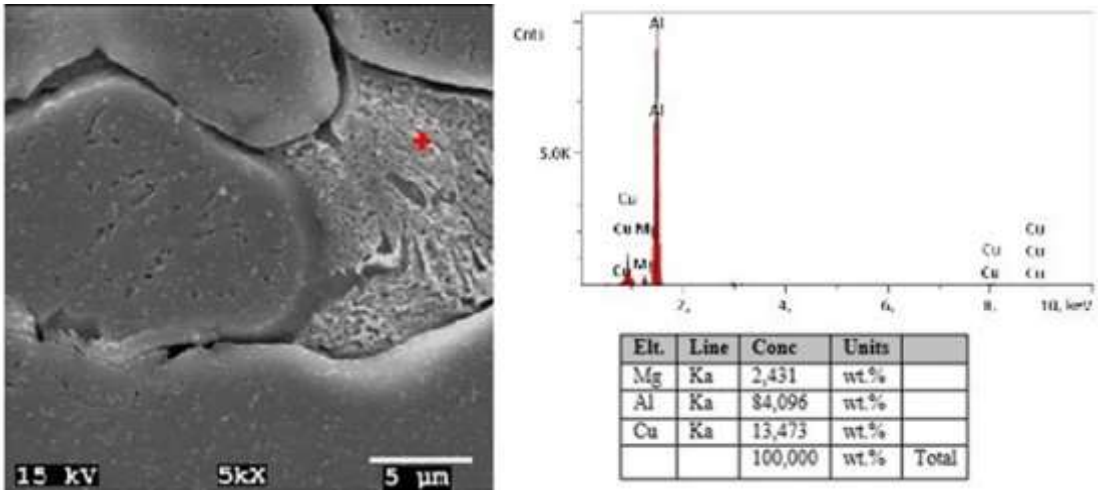


Figure 5. a) SEM image, (b) EDX elemental maps of the as-cast 8090 alloy with Gd addition.

In Figure 5, it was seen that Cu has a large concentration gradient in the alloy with Gd addition. Cu element segregated to the interdendritic regions during solidification due to the high solute partition coefficient and formed the α-Al + T2 (Al_6CuLi_3) eutectic structure at the end of solidification (Figure 6). On the contrary, as seen in Figure 4, segregation of Fe, Si and partly Mg alloying elements decreased in the interdendritic regions in the Gd containing alloy. As evidence of this, Mg peak originating from the signal coming from the matrix was observed in the EDX analyses performed during the SEM examination. This situation shows that the solid solubility within and between dendrites increased and the micro segregation of alloy elements decreased. The distribution of Li element could not be determined by EDX analysis due to its small atomic number.



Elt.	Line	Conc	Units	
Mg	Ka	2,431	wt.%	
Al	Ka	84,096	wt.%	
Cu	Ka	13,473	wt.%	
		100,000	wt.%	Total

Figure 6. SEM-EDX analysis of eutectic pahse in Gd containing 8090 alloy.

The first mechanism of the dendritic structure refining in the Gd-added 8090 Al-Li alloy is that the Gd-containing phases shown in Figure 7 act as nucleation sites during solidification. The second mechanism is that the Gd element becomes increasingly enriched at the interface between the solid and the liquid during cooling after casting, thus increasing the degree of supercooling of the composition and preventing the Al atoms from entering the crystal; therefore, the grains cannot grow further. These two situations ensure that the solidification structure of the casting alloys is refined [Brazolin et al., 2016; Xu, 2008; Zhang et al., 2021].

3.2. Hardness

The microhardness values of 8090 Al-Li alloy and after Gd addition were determined as 44 HV and 127.93 HV, respectively. The hardness increases increased by 190.75%, indicating that Gd addition was significantly effective on the hardness of 8090 alloy. Xu et al. reported that the hardness of Mg-Gd alloys with different grain sizes was almost the same and the hardness value increased as the amount of Gd in the alloy increased [Xu et al., 2018].

3.3. Tensile Properties

Figure 7 shows the mechanical properties of the alloys after tensile testing, obtained from typical engineering stress-strain curves. As seen in figure, tensile tests of the alloys examined in the as-cast state revealed that the tensile strength of 171.40 MPa increased to 313.84 MPa with the addition of Gd, while the elongation decreased from 29.53% to 11.09%.

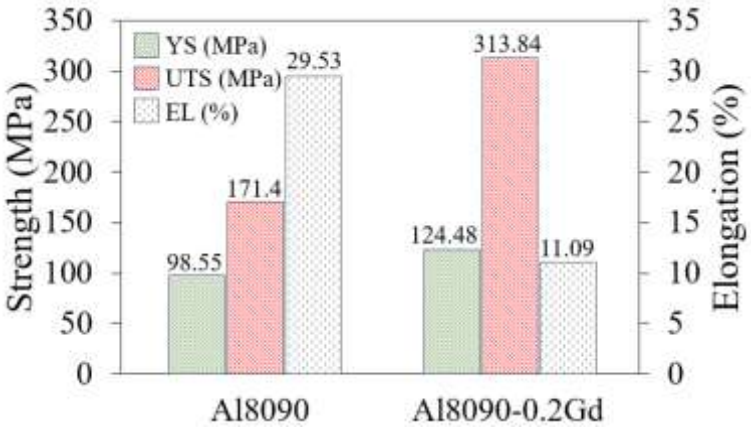


Figure 7. Mechanical values of the alloys.

The refining of the dendritic structure by Gd addition was advantageous in terms of the strength properties of the alloy. The smaller the dendritic structure, the greater the resistance to deformation and hence the tensile strength and yield strength. In both alloys, and especially in the as-cast microstructure of the alloy containing Gd, various coarse secondary phases formed during solidification along the interdendritic boundaries were observed. These brittle phases have a higher stress concentration and thus provide a possible path for crack propagation. Therefore, the ductility was lower in the Gd containing 8090 Al-Li alloy. This is in agreement with studies in the literature [Hajjioui et al., 2022], which revealed that the δ (AlLi) phase, which acts as the primary strengthening phase in Al-Li alloys, also acts as a brittle phase.

4. Conclusion and Recommendations

In this article, the effect of Gd rare earth element addition on the casting microstructure and mechanical properties of 8090 Al-Li alloy was investigated.

i. After adding Gd rare earth element, the microstructure of 8090 Al-Li alloy in the as-cast state was refined. It was observed that Al_3CuGd phase was formed in the alloy with the addition of Gd. According to the results obtained in the studies carried out on Al–Zn–Mg–Cu–Zr alloys, this phase was found to have the potential to strongly pinning dislocations and sub-grain migration and prevent further recrystallization in the subsequent processes [Zhang et al., 2012]. In addition, the T2 (Al_6CuLi_3) eutectic structure increased in the interdendritic regions in the microstructure.

ii. The hardness was found to be higher in the alloy containing Gd due to the formation of hard secondary phase particles in the structure.

iii. Both the thinning of the casting microstructure and the formation of Gd containing phases increased the strength values of 8090 Al-Li alloy, while the elongation values decreased.

iv. The micro-segregation of the 8090 Al-Li alloy significantly reduced after adding Gd. Meanwhile, the grain relative solid-solubility of Fe, Si and Mg elements could be increased as seen in elemental mapping.

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IMPROVING SOLAR PANEL PERFORMANCE: ENVIRONMENTAL COMPATIBILITY OF NANO COATINGS

GÜNEŞ PANELİ PERFORMANSINI İYİLEŞTİRME: NANO KAPLAMALARIN ÇEVRESEL UYUMU

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ÖZET

Güneş panellerinin verimliliği, küresel enerji dönüşüm sürecinin karşılaştığı en önemli teknik zorluklardan biridir. Fotovoltaik hücrelerin tasarımında kaydedilen önemli gelişmelere rağmen, panellerin sahadaki performansı; ışık yansıması, toz birikimi, nem gibi dış çevresel faktörler ve ayrıca ultraviyole (UV) ışınlar ile sıcaklık dalgalanmaları nedeniyle sıklıkla azalmaktadır. Bu faktörler, elektrik enerjisine dönüştürülebilecek enerjinin önemli bir kısmının kaybına neden olur ve bu durum, güneş enerjisi teknolojilerinin ekonomik fizibilitesini ve çevresel sürdürülebilirliğini olumsuz etkiler.

Bu bağlamda, nano kaplamalar, güneş panellerinin performansını niteliksel olarak artırma potansiyeline sahip yenilikçi bir çözüm olarak öne çıkmaktadır. Nano teknoloji, maddeyi atom ve molekül düzeyinde kontrol ederek; yansıma azaltıcı, kendini temizleyebilen ve ışık emilimini artırabilen akıllı yüzey kaplamalarının tasarlanmasına imkân tanır. Bu özellikler, zorlu çevre koşullarında bile güneş hücrelerinin verimliliğini önemli ölçüde artırmaktadır.

Anahtar Kelimeler: Enerji, güneş paneli, nano kaplama, verimlilik.

Nanokaplamalar nedir?

Nanokaplamalar ve Nanoteknoloji Kavramı:

Nanoteknolojinin enerji alanındaki en dikkat çekici uygulamalarından biri olan nanokaplamalar, genellikle 100 nanometreden daha ince olan ve yüzeylere uygulanan ultra ince film tabakalarıdır. Bu kaplamalar, atomik veya moleküler düzeyde kontrol edilen nanomalzemelerle üretilir. Böylece, aynı malzemenin geleneksel formlarına kıyasla tamamen farklı fiziksel ve kimyasal özellikler kazanır. Güneş paneli yüzeyi ile çevre arasındaki etkileşimi düzenleyerek, genel verimliliği artırma potansiyeli taşırlar.

Nanokaplamalar ile Geleneksel Kaplamalar Arasındaki Temel Farklar:

Nanokaplamalar, işlev ve yapı açısından geleneksel kaplamalardan köklü şekilde ayrılır. Geleneksel kaplamalar, genellikle mekanik koruma, ısı yalıtımı veya korozyon direnci gibi temel işlevler için tasarlanırken; nanokaplamalar, optik yansımayı azaltma, kendi kendini temizleme, ultraviyole ışınlara karşı koruma ve termal/elektriksel iletkenliği artırma gibi "akıllı" işlevlere sahiptir. Bu temel fark, nanokaplamaları sadece bir yüzey kaplaması olmaktan çıkarıp, fotovoltaik sistemlerin verimliliğini artıran etkili bir araç hâline getirir.

Optik Şeffaflık ve Işık Emilimini Artırmadaki Rolü:

Güneş panelleri bağlamında nanokaplamaları etkili kılan temel özelliklerden biri, yüksek optik geçirgenliktir. Titanyum dioksit (TiO_2) ve silika (SiO_2) gibi nanomalzemeler, görünür ışığı yüksek oranda geçirebilme kapasitesine sahip olup yansımayı minimum düzeye indirir. Bu sayede güneş hücresine daha fazla güneş ışığı ulaşır ve fotovoltaik dönüşüm süreci daha verimli hâle gelir. Bu özellik özellikle silikon bazlı hücrelerde büyük önem taşır.

Buna ek olarak, nanokaplamaların yapısal tasarımı, ışık yansımasını azaltmak için kırılma indeksinin katmanlar arasında optimize edilmesini sağlar. Bu, özellikle ışığın düşük açılardan geldiği sabah veya akşam saatlerinde daha fazla güneş ışığının emilmesini mümkün kılar. Böylece güneş panelinin günün her saatinde daha yüksek verimle çalışması sağlanır.

Kendi Kendini Temizleme Özelliği ve Fotokatalitik Tepkimeler:

Bu kaplamaların sunduğu bir diğer önemli özellik ise kendi kendini temizleyebilme yeteneğidir. Süper hidrofobik olarak tasarlanan yüzeyler, su damlacıklarının yüzeyde kayarak toz ve kirleri beraberinde taşımasını sağlar. Bu etki, fotokatalitik özellik gösteren TiO_2 gibi malzemelerle birleştirildiğinde daha da güçlenir; UV ışığı altında organik kirleticiler kimyasal olarak parçalanarak yüzeyin temiz kalmasına katkı sağlar.

Isı Direnci, Çevresel Koruma ve Panel Ömrünün Uzatılması:

Son olarak, nanokaplamalarda kullanılan malzemeler, yüzeylerin ısıya ve mekanik aşınmaya karşı direncini artırır. Bu da güneş panellerinin ömrünü uzatır ve sıcaklık dalgalanmaları veya nem gibi çevresel faktörlerden kaynaklanan bozulmaları önler. Ayrıca ZnO ve Al_2O_3 gibi bazı nanomalzemeler, ısının hücre yüzeyinden daha verimli bir şekilde dağılmasını sağlayarak sıcaklığa bağlı verim kayıplarını azaltır.

Nanokaplamalar ile Performans Artırma Mekanizması:

Işığın Yansımasını Azaltma ve Emilimini Artırma:

Güneş panellerine ulaşan ışığın bir kısmı cam yüzeyden yansır ve bu, toplam verimliliği azaltır. Anti-reflektif nanokaplamalar, hava ile cam arasındaki kırılma indis farkını kademeli olarak

azaltarak yansıma kayıplarını minimuma indirir. Özellikle SiO_2 ve TiO_2 gibi malzemeler, optik özellikleri nedeniyle bu amaçla tercih edilir. Yapılan çalışmalar, bu tür kaplamaların ışık emilimini %5-10 oranında artırabildiğini göstermektedir.

Işığın Güneş Hücresine Geçişinin İyileştirilmesi:

Nanokaplamalar, yüzeydeki düzensiz yansıma ve saçılmayı azaltarak ışığın güneş hücresine daha doğrudan geçmesini sağlar. Bu, özellikle çok katmanlı yapıya sahip veya düşük ışık koşullarında çalışan paneller için büyük avantaj sağlamaktadır.

Kendi Kendini Temizleme Özelliği ve Toz Birikiminin Azaltılması:

Nanokaplamalar, su itici (superhidrofobik) özellikleri sayesinde yüzeyde su damlalarının yuvarlanarak toz ve kirleri temizlemesini sağlar. Özellikle TiO_2 gibi fotokatalitik malzemeler, organik kirleri parçalayarak kendi kendini temizleyen yüzeyler oluşturur. Bu sayede verimlilik kaybı en aza iner.

UV Işınlarına ve Çevresel Etkilere Karşı Koruma ve Ömrünün Uzatılması:

Güneş panelleri, UV ışınları ve zorlu çevresel koşullar nedeniyle zamanla bozulabilir. ZnO ve TiO_2 bazlı nanokaplamalar, bu zararlı ışınları absorbe ederek panel yüzeyini korur. Aynı zamanda nem, aşınma ve yüksek sıcaklık gibi faktörlere karşı dayanıklılığı artırır. Tüm bu işlevler sayesinde nanokaplamalar, güneş panellerinin işlevsel ömrünü %20-30 oranında uzatabilir. Bu da, özellikle uzun vadeli yatırım ve bakım maliyetleri açısından büyük avantaj sağlar.

Güncel Uygulama Örnekleri ve Araştırmalar:

TiO_2 ve ZnO Kaplamaları ile Performans Artışı:

Bu konudaki önemli bir çalışma, 2020 yılında Optik dergisinde yayımlanmıştır. Çalışmada, boya duyarlı güneş pilleri (DSSC) için TiO_2 nanotüpleri ve ZnO nanorodlarından oluşan hibrit anotlar geliştirilmiştir. Elektrokimyasal biriktirme ve anotlama yöntemleriyle üretilen bu yapılar, ışığın etkin şekilde emilmesini sağlayan gözenekli nano yapılar oluşturmuştur. Sonuçlar, güneş pili veriminin %0,81'den %1,67'ye yükseldiğini ve bu sayede %106'lık bir iyileşme sağlandığını göstermiştir. Bu gelişme, daha geniş bir yüzey alanı, düşük yansıma kaybı ve daha hızlı elektron taşınımı sayesinde mümkün olmuştur.

Yüksek Güneşlenme Ortamlarında ZnO Kaplamalarının Kullanımı:

2024 yılında Sustainability dergisinde yayımlanan bir çalışmada, kristal silikon güneş hücrelerinin yüzeyine ZnO nano kaplamalar püskürtülmüştür. Bu kaplamalar yüksek ışık geçirgenliği, düşük yansıma ve UV ışınlarına karşı koruma gibi özelliklere sahiptir. Deneysel sonuçlar, kısa devre akımı ve açık devre voltajında anlamlı artışlar göstermiştir. Ayrıca, ZnO kaplamalı hücrelerin sıcaklık değişimlerine ve dış çevresel etkilere karşı daha dayanıklı olduğu belirlenmiştir. Genel verimlilikte %13,5'e kadar bir artış gözlenmiştir.

Çöl Ortamlarında Toz Direncine Sahip SiO_2 Kaplamaları :

2024 yılında Umman'da gerçekleştirilen bir çalışmada, SiO_2 nano kaplamaya sahip güneş panelleri test edilmiştir. Bu kaplamalar, kendini temizleyen süperhidrofobik yüzey özelliklerine sahiptir. SiO_2 kaplamalı panellerin, toz ve nem içeren zorlu çöl koşullarında %31,7 daha yüksek verimlilik gösterdiği; ayrıca manuel temizliğe tabi tutulan panellerden %9,6 daha verimli olduğu tespit edilmiştir. Bu çalışma, kaplamanın çevresel temizlik yükünü azalttığını ve verimliliği koruduğunu göstermektedir.

Ekonomik ve Çevresel Değerlendirmeler :

Nanokaplamaların Üretim ve Uygulama Maliyetlerinin Enerji Kazancıyla Karşılaştırılması :

Güneş panellerine nanokaplama uygulanması fikri, yalnızca teknik açıdan değil, ekonomik açıdan da dikkatle değerlendirilmelidir. Kaplamalar sayesinde yansıma azalmakta, ışık emilimi artmakta ve panel ömrü uzamaktadır. Ancak bu avantajların üretim ve uygulama maliyetleri ile dengelenmesi gerekmektedir.

Yapılan araştırmalar, kullanılan nanomalzemeye ve kaplama yöntemine bağlı olarak maliyetlerin değiştiğini göstermektedir. Örneğin, SiO_2 ve ZnO gibi maddeler daha uygun fiyatlı ve yaygınken, kompleks metal oksitler veya çok işlevli nanoparçacıklar daha yüksek maliyetlidir. Ancak uzun vadede, bu kaplamalar sayesinde verimlilikte %20'ye kadar artış, temizlik ihtiyacının azalması ve bakım masraflarının düşmesi sayesinde maliyetler 2-4 yıl içinde geri kazanılabilmektedir. Güneş paneli ömrü 25 yıl olduğundan, bu durum yatırımcılar için sürdürülebilir ve ekonomik bir tercih haline gelmektedir.

Nanokaplamaların Çevresel Etkisi :

Her ne kadar yenilenebilir enerji çevresel açıdan olumlu bir adım olsa da, nanomalzeme üretimi çevresel bazı riskleri beraberinde getirebilir. Özellikle nano atıkların su kaynaklarına veya doğaya karışması, biyolojik sistemler üzerinde toksik etkilere yol açabilir. 2023 yılında Journal of Cleaner Production dergisinde yayımlanan bir çalışmaya göre, TiO_2 ve ZnO gibi metal oksit nanoparçacıkları çevredeki mikroorganizmalar üzerinde oksidatif stres oluşturarak ekosisteme zarar verebilir.

Bu nedenle, çevre dostu üretim süreçleri, güvenli çalışma ortamları ve geri dönüşüm stratejileri büyük önem taşır. Buna rağmen, nanokaplamaların dolaylı çevresel katkıları büyüktür: su ve kimyasal kullanımı azalır, enerji verimliliği artar ve fosil yakıt ihtiyacı düşer. Bu durum, uygun çevresel yönetimle birlikte, bu teknolojinin sürdürülebilirliğini desteklemektedir.

Nanokaplamaların Sürdürülebilirliği ve Hammadde Erişilebilirliği:

Nanokaplamalarda kullanılan hammaddelerin büyük çoğunluğu doğada bol miktarda bulunur. TiO_2 ve ZnO gibi maddeler tarım veya gıda sektörleriyle rekabet içinde olmadıkları için sürdürülebilirlik açısından avantajlıdır. Ayrıca bu maddeler geri dönüştürülebilir olup, birçok endüstride tekrar kullanılabilirler. Bu da onları çevresel açıdan uzun vadeli bir çözüm haline getirir.

Son yıllarda Çin, Almanya ve Güney Kore gibi ülkelerde nanomalzeme üretimi arttıkça, bu malzemelerin maliyetleri düşmüştür. Bu durum, Türkiye gibi gelişmekte olan ülkelerin bu teknolojiyi benimsemesi için bir fırsat sunmaktadır. Yerli üretimin teşvikiyle, hem maliyetler azalmakta hem de dışa bağımlılık azalmaktadır.

Sonuç:

Nanokaplamalar, güneş panellerinin verimliliğini artırma alanında en umut verici teknolojilerden biri olarak öne çıkmaktadır. Yansıma, toz birikimi ve zorlu çevresel koşullar gibi temel sorunları ele alma yeteneği sayesinde, TiO_2, SiO_2 ve ZnO gibi nanomalzemelerin kullanımı, optik emilimde önemli iyileşmelere, ısıl kayıpların azaltılmasına ve sistemin kullanım ömrünün uzatılmasına katkı sağlamaktadır.

Bu kaplamaların kendi kendini temizleme, yansıma azaltma, UV koruma ve pasif soğutma gibi çok yönlü özellikleri, farklı iklim ve çevre koşullarında etkili çözümler sunmalarını mümkün

kılmaktadır. Yapay zekâ destekli akıllı nanokaplama sistemlerine yönelik eğilim, kendi kendine optimize olabilen, daha az bakım gerektiren, güvenilir güneş enerjisi sistemlerinin inşasında stratejik bir adım olarak değerlendirilmektedir.

Ancak, laboratuvar ölçeğinden endüstriyel uygulamaya geçiş hâlâ birçok zorluk içermektedir. Üretim maliyetlerinin düşürülmesi ve kullanılan nanomalzemelerin çevresel anoktada, araştırma kurumları, üretici firmalar ve politika yapıcılar arasında daha güçlü bir iş birliği gereklidir.

Küresel iklim değişikliği ve yenilenebilir enerjiye artan talep ışığında, nanokaplama teknolojilerine yapılacak yatırımlar, fosil yakıtlara olan bağımlılığı azaltmak ve temiz, verimli bir enerji geleceği inşa etmek isteyen ülkeler için stratejik bir tercih olacaktır.

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OPTIMIZATION OF PRINTING PARAMETERS IN 3D FDM PRINTERS: AN EXPERIMENTAL APPROACH BASED ON PERFORMANCE AND QUALITY CRITERIA

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ABSTRACT

In this study, the effects of printing parameters on mechanical and surface performance in Fused Deposition Modeling (FDM) type three-dimensional (3D) printers were analyzed experimentally. The aim of the research is to determine the most suitable production conditions based on tensile strength and surface roughness criteria. Within the scope of experimental studies, layer thickness (LT), fill rate (ID), print speed (PS), nozzle diameter (ND) and print temperature (PT) were selected as printing parameters. Experiments were carried out on Flashforge Adventurer 5M Pro FDM printer using PETG filament and Taguchi L27 orthogonal array was preferred for experimental design. Produced samples were subjected to tensile test and surface roughness measurement, and the obtained data were evaluated by analysis of variance (ANOVA). The results showed that especially layer thickness and fill rate parameters had statistically significant effects on tensile strength. In terms of surface quality, thin-layer and low-speed prints gave better results. The most suitable printing conditions were determined as LT: 0.1 mm, ID: 80%, PS: 50 mm/s, ND: 0.4 mm and PT: 235°C. With this parameter combination, tensile strength increased by 25.6% and surface roughness improved by 31.9%. This study provides a scientific basis for optimizing the printing process for researchers and industrial users who want to improve quality in FDM production.

Keywords: FDM, 3D Printer, Parameter Optimization, Taguchi Method, Surface Quality, Tensile Strength

Introduction

Additive manufacturing (AM) is rapidly becoming widespread thanks to its advantages such as success in complex geometries, customization and production flexibility as an alternative to traditional manufacturing methods. Among these technologies, Fused Deposition Modeling (FDM) stands out with its low-cost equipment and wide material compatibility (Ouazzani et al., 2023; Pérez et al., 2018; Zaman et al., 2019). FDM is based on the principle of controlled melting of thermoplastic filament and laying on top of each other in layers. However, in this process, undesirable variations in product quality occur as a result of complex interactions of production parameters. In particular, performance criteria such as tensile strength (σ_t) and surface roughness (Ra) are directly affected (Mohamed et al., 2016; Kam et al., 2023; Altan et al., 2018).

In recent years, some studies have aimed to investigate the effect of FDM process parameters on product performance and have made optimization suggestions by combining experimental methods and statistical analysis approaches (Tamaşag et al., 2022). In particular, the decisive effects of parameters such as nozzle temperature, layer thickness, fill rate, printing speed, table temperature and printing orientation on mechanical and surface properties have been emphasized (Khan et al., 2022; Zaman et al., 2019; Yang et al., 2019).

Ouazzani et al., (2023) stated that the most critical parameter in terms of surface roughness in FDM prints made with Acrylonitrile Butadiene Styrene (ABS) material is the layer height. Similarly, Pérez et al., (2018) proposed a strategy for optimizing critical parameters in order to improve surface quality. Kam et al., (2023) detailed the effect of printing parameters on mechanical properties with the Taguchi method in their study on PA12 material. In the study conducted by Mohamed et al., (2016), they stated that the dynamic mechanical performance of Polycarbonate (PC) and ABS samples can be improved through design.

Studies on biodegradable polymers such as Polylactic Acid (PLA) are also noteworthy. Afshari et al., (2024) experimentally demonstrated the effect of parameters optimized with Response Surface Methodology (RSM) on mechanical performance in parts produced with PLA material. Heidari-Rarani et al., (2022) tried to maximize the tensile strength of PLA samples using the Taguchi approach. Similarly, Altan et al., (2018) evaluated both surface roughness and tensile strength criteria together.

It has been mentioned in the literature that in order to obtain high-quality FDM outputs, parameters should be optimized together and parametric interactions should be taken into account rather than individual effects (Zaman et al., 2019; Moradi et al., 2023; Moradi et al., 2021). However, very few studies have conducted a systematic evaluation from a multi-criteria decision-making perspective by evaluating both surface quality and mechanical performance simultaneously. This situation reveals the need for comprehensive experimental and statistical studies to make FDM technology more efficient in terms of performance and quality.

In this study, performance criteria such as tensile strength and surface quality of parts produced with the FDM method, which stands out with its advantages such as low cost, material accessibility and ease of use, were examined. The aim of the study is to determine the optimum production conditions by experimentally analyzing the effects of five basic parameters used in FDM production (layer thickness (LT), fill rate (ID), printing speed (PS), nozzle diameter (ND) and printing temperature (PT)) on product quality.

Materials and Methods

Polyethylene Terephthalate Glycol (PETG) filament (Figure 1.a) was preferred in the production of the samples. Their geometries were designed using SolidWorks software in accordance with the ASTM D638 TypeV standard. Then, they were sliced using FlashPrint software. The production process was carried out with a FlashForge Adventurer 5M Pro (Figure 1.b) model FDM type 3D printer, and all samples were produced in a horizontal position parallel to the X–Y plane of the printer and at a table temperature of 70 °C. Experimental planning was made based on the Taguchi L27 orthogonal array. Mechanical performance evaluations were carried out using a Shimadzu AGS-X universal testing machine (Kyoto, Japan). A 5 kN capacity load cell was used in the device and the experiments were carried out with a tensile speed of 5 mm/min, a temperature of 23 °C ± 2 °C, and a relative humidity of 50 ± 5%. The maximum tensile stress (σ_t, MPa) values were recorded as the test output. Surface quality analyses were performed with Mitutoyo SJ-210 portable profilometer; based on 0.8 mm cut-off, 5.6 mm scanning length and average surface roughness (Ra) parameter, the average of the measurements taken from 3 different points in the central region of each sample was taken into account. Statistical analysis of the data was performed with Minitab 21 software; the effects of the parameters were evaluated with one-way analysis of variance (ANOVA) during the analysis process. Optimization was performed on Taguchi Signal/Noise (S/N) ratios and the contribution rates of each parameter on the performance outputs were calculated as percentages and the effect degrees were determined.



(a) (b)

Figure 1. Filament and printer used in the 3D printing process

Properties of Materials Used

In experimental studies, PETG material, some of the properties of which are given in Table 1, was used. PETG is a thermoplastic widely used in FDM type 3D printers and stands out with its high tensile strength, impact resistance and thermal stability properties. In addition, it contributes to obtaining low roughness on the surface by providing good adhesion between layers during production. Thanks to its shape stability, which is an important output for 3D printing, this material, which increases the reliability of experimental repetitions, is also frequently preferred due to its low deformation among polymer types during the printing process. Thus, it was aimed to select the type of material used with properties that can meet these expectations in order to evaluate both mechanical performance and surface quality in an optimized way.

Table 1. PETG filament technical specifications

Features	Value
Filament diameter	1.75 mm ± 0.05 mm
Density	1.27 g/cm³
Melting temperature range	220–250°C
Manufacturer	Elas
Color	Transparent
Material type	Thermoplastic polyester

Experimental Design: Parameters and Levels

The experimental design was created based on the Taguchi method and the L27 orthogonal array was preferred in order to systematically examine a large number of parameter combinations with a minimum number of trials, as seen in Table 2. This experimental design allowed each parameter to be evaluated at three different levels and enabled statistically significant analysis of interactions between parameters. A total of five printing parameters (LT, ID, PS, ND and PT) were considered at three levels (Level 1, Level 2, Level 3) each, creating 27 unique experimental combinations. This method provided an efficient analysis process in terms of both time and resources by preserving the experimental database while reducing the number of experiments. It also allowed for the comparative evaluation of individual and relative parameter effects on performance outcomes.

Table 2. Experimental parameters and levels

Parameters	Units	Level 1	Level 2	Level 3
Nozzle Diameter (ND)	mm	0.4	0.6	0.8
Layer Thickness (LT)	mm	0.1	0.2	0.3
Infill Density (ID)	%	20	50	80
Print Speed (PS)	mm/s	30	50	70
Print Temperature (PT)	°C	220	235	250

Sample Design and Production Process

The test samples used in this study were designed according to ASTM D638 Type V standard with the dimensions shown in Figure 2. The geometric modeling process was carried out with SolidWorks CAD software, which is widely used in the industry and offers high accuracy; then, the slicing process was performed with FlashPrint software in order to make it manufacturable in a 3D printer. All samples were produced in a horizontal position parallel to the X–Y plane of the 3D printer in order to balance the effect of the orientation of the layer structure on the mechanical performance. The table temperature was fixed at 70 °C during printing to optimize material-based adhesion and dimensional stability. For experimental verification and statistical significance, each parameter combination was produced with 3 repetitions; a total of 81 samples were obtained within the scope of 27 different parameter sets. This systematic approach ensured that the variance was minimized and the reliability of the analyses was increased.

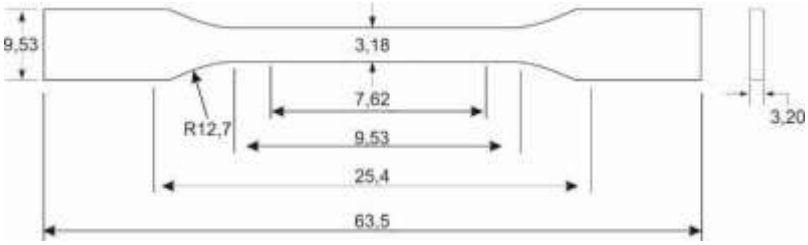


Figure 2. ASTM D638 TypeV specimen geometry (ASTM D638-22, 2022)

Testing Procedures

Tensile test

Tensile tests were performed using Shimadzu AGS-X model universal testing machine, which provides high accuracy and repeatability. A maximum capacity of 5 kN load cell was preferred in the experiments, thus providing sufficient sensitivity. During the tests, the tensile speed was fixed as 5 mm/min in accordance with ASTM D638 standard. The experimental environment was kept under control to minimize the effect of environmental conditions on mechanical properties; temperature was fixed as 23°C ± 2°C and relative humidity was fixed as 50 ± 5%. As the main performance output of the test, the maximum tensile stress (σ_t, MPa) value, which represents the highest load that the samples can carry, was measured and this value was evaluated in order to analyze the effect of different parameters on mechanical performance.

Surface roughness (R_a) measurement

Surface roughness measurements were performed using a high-precision portable profilometer, the Mitutoyo SJ-210. A cut-off value of 0.8 mm and a scan length of 5.6 mm were used as the basis for the measurements. These values were selected in accordance with the ISO 4287 standard and were preferred in order to correctly distinguish the wavelength components of the surface. Three different measurement points taken at equal intervals from the central region of the sample were evaluated to represent the surface quality of each sample, and the results were reported according to the reliability principle by taking the arithmetic average of the Ra values obtained from these points. This method increases the measurement reliability by taking into account the homogeneity of the surface at both microscopic and macroscopic levels.

Statistical evaluation

The analysis of experimental data was carried out using Minitab 21 software in order to make statistical significance and optimization evaluations in a healthy way. More than one statistical method was integrated in the analysis process. First, one-way analysis of variance (ANOVA) was applied to statistically reveal the effect of each printing parameter (LT, ID, PS, ND and PT) on the performance outputs. Thanks to this analysis, it was determined which parameters had a significant effect on the results. In addition, S/N ratios were calculated for the optimization of each output within the framework of Taguchi experimental design. In this context, the evaluation was made based on the criterion of "bigger is better" for tensile strength performance and the criterion of "smaller is better" for surface roughness (Ra). Finally, the relative effect of each parameter within the total variance was calculated as a percentage, and

the effect degrees and contribution rates were determined; thus, the effect of the parameters on quality characteristics was revealed.

Findings and Discussion

Tensile strength (σ_t) and surface roughness (Ra) outputs of parts produced with FDM technology using PETG filament were analyzed. Experimental data were interpreted to reveal the effects of parameters on the output and supported by ANOVA and S/N analysis.

Tensile Strength Results

As a result of tensile tests performed on samples produced with different parameter combinations, the strength values were measured in the range of 30.2 ±1.2 MPa to 42.1 ±1.4 MPa. The results of some of the test samples are given in Table 3. The highest tensile strength was obtained with 42.1 MPa with 0.1 mm layer thickness and 80% filling ratio (Exp. no: 5).

Table 3. Tensile strength results for selected parameter combinations

Exp. No	LT (mm)	PS (mm/s)	ND (mm)	ID (%)	PT (°C)	σ_t (MPa)
1	0.1	30	0.4	20	220	35.2
5	0.1	50	0.4	80	235	42.1
11	0.2	50	0.6	50	235	37.3
14	0.2	50	0.6	50	235	37.4
18	0.3	70	0.6	20	250	31.0
22	0.3	70	0.8	20	250	30.2
24	0.3	70	0.8	80	250	33.8
25	0.1	30	0.8	50	220	36.5
27	0.2	70	0.4	80	235	38.2

Surface Roughness (Ra) Results

The Ra values obtained as a result of surface roughness measurements varied between 6.2 µm and 11.8 µm. It was observed that thin layers and low printing speeds improved the surface quality. The results of some of the experiments are given in Table 4. Accordingly, the best surface roughness value was obtained from printing with 0.1 mm layer thickness, 30 mm/s printing speed and 0.4 mm nozzle diameter (Exp. no. 1).

Table 4. Surface roughness results for selected parameter combinations

Exp. No	LT (mm)	PS (mm/s)	ND (mm)	Ra (µm)
1	0.1	30	0.4	6.2
5	0.1	50	0.4	6.7
11	0.2	50	0.6	8.5
14	0.2	50	0.6	8.4
18	0.3	70	0.8	11.8
22	0.3	70	0.8	11.7
24	0.3	70	0.8	10.2
25	0.1	30	0.4	6.4
27	0.2	70	0.6	9.1

Parameter Impact Analysis and Discussion

As a result of the variance analysis and contribution rate calculations, the effects of printing parameters on both mechanical performance (tensile strength, σ_t) and surface quality (average surface roughness, Ra) were statistically determined (Figure 3). Layer thickness stood out as the parameter with the highest effect on both performance outputs. It contributed 41.2 ±0.8% for tensile strength and 52.6 ±1.1% for surface roughness. This shows that layer thickness directly affects both the structural integrity of the material and the surface form. The fullness ratio, in particular, showed a significant effect on tensile strength and contributed 26.7 ±1.3%. Thus, it was determined that the internal structural density of the sample had a strong relationship with mechanical resistance. Low printing speed was another prominent parameter in terms of surface quality and showed a 21.4 ±0.9% improvement on the Ra value, revealing the roughness-improving effect of material accumulation and layer transitions during the printing process. Nozzle diameter and printing temperature were evaluated as secondary effective parameters in terms of both σ_t and Ra; although the effect of these parameters is limited, it is thought that they can contribute to the optimization process with fine tuning. These findings have been guiding in determining the relative effects of the parameters on performance outputs and their prioritization levels.

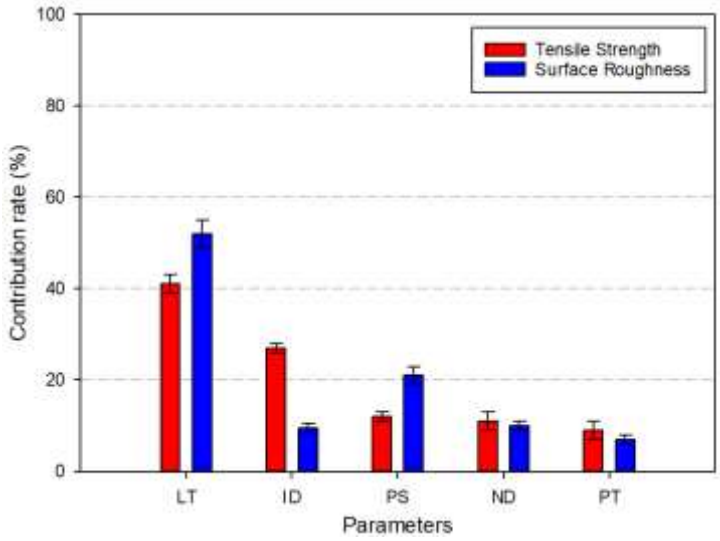


Figure 3. Parameter effect analysis graph

Optimum Parameter Combination

As a result of the evaluation of the Signal/Noise (S/N) analysis results and experimental observations together, the optimum printing parameters that maximize both mechanical performance (σ_t) and surface quality (Ra) were determined. In terms of layer thickness, the level of 0.1 mm provided both the highest tensile strength and the lowest surface roughness value, offering a two-way performance advantage. In terms of filling ratio, 80% significantly increased the strength of the samples thanks to the increase in internal structure density and represented the optimum condition in terms of mechanical durability. In terms of printing speed, 50 mm/s provided an ideal balance between production time and surface quality, while maintaining quality and making the process efficient. The nozzle diameter of 0.4 mm increased the printing sensitivity and positively affected the surface smoothness by ensuring that the material flow became more stable thanks to the thinner diameter. Finally, the value of 235 °C for printing temperature ensured that the PETG filament reached ideal flow conditions, optimized the adhesion between the layers and increased the overall production quality. This optimum parameter combination has created a balanced and applicable production recipe that maximizes both durability and surface quality.

Conclusion and Recommendations

In this study, the effects of printing parameters used in FDM (Fused Deposition Modeling) type 3D printers on mechanical performance (tensile strength) and surface quality (average surface roughness, Ra) were analyzed by experimental methods. PETG filament, which is widely used and offers high strength-surface quality balance, was preferred in production. Experiments were planned systematically based on Taguchi L27 orthogonal array and each parameter was examined at three levels. The obtained data were statistically analyzed with Minitab 21 software and the most effective parameters were determined via ANOVA and S/N ratios. According to the findings;

- While layer thickness is the parameter that most affects both tensile strength and surface quality, the fullness ratio increased the rigidity of the internal structure of the sample.
- Printing speed was determined as the second most important factor on surface roughness, and significant decreases in roughness were observed especially with speeds below 50 mm/s.
- Nozzle diameter and printing temperature, although having secondary effects, played a supporting role in general printing quality when brought to optimum values.
- The most suitable printing conditions were determined as 0.1 mm layer thickness, 80% fullness ratio, 50 mm/s printing speed, 0.4 mm nozzle diameter and 235°C printing temperature. With this parameter combination, tensile strength was increased by 25.6% and surface roughness was reduced by 31.9%.

The results obtained support the findings of studies in the literature such as Chacón et al. (2017), Rodríguez et al. (2003) and Singh et al. (2016); in particular, the decisive role of layer thickness on performance has been strongly demonstrated in this study. In this respect, the L27-based experimental structure that optimizes five parameters simultaneously offers an original contribution to the literature, specifically for PETG. In terms of application, this parameter set

is recommended in industrial scenarios where high strength and surface quality are demanded together.

In future studies, different filament types (e.g. ABS, PLA-Carbon Fiber, PP, PC and TPU) can be analyzed with similar systems and 3D scanning technologies can be integrated in surface characterization. In addition, advanced optimization techniques such as multi-criteria decision making, artificial intelligence-based modeling or regression analysis can be used. In addition, thanks to the obtaining of quality surfaces at lower printing speeds, a decrease in energy consumption can be achieved by reducing the need for reprocessing processes after production. As a result, it has been evaluated that it can make positive contributions to sustainable production strategies.

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INVESTIGATION OF THE EFFECT OF MOLYBDENUM SULFIDE ON THE DEGRADATION OF VANILLIN BY ELECTRO-FENTON METHOD

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ABSTRACT

Vanillin is produced synthetically and used as a sweetener and fragrance in many different areas. For this reason, synthetic vanillin can be discharged from wastewater to surface waters without being biodegraded. The electro-Fenton method is an environmentally friendly and effective method that allows the on-site production of hydroxyl radicals used for organic pollutants resistant to degradation. In this study, CF@MoS_2 cathode production was carried out by loading molybdenum sulphide onto the carbon felt (CF) electrode surface using the hydrothermal method. The prepared cathode was characterized with SEM images, while the powder MoS_2 structure was defined with XRD and EDS analyses. Vanillin degradation was carried out at pH 3 using CF and CF@MoS_2 cathodes. Vanillin degradation was carried out by the electro-Fenton method at constant currents of 50, 100, 200 and 300 mA. While the change in vanillin concentration was monitored by HPLC analysis, total organic carbon contents were determined for mineralization. It was observed that the most effective oxidation occurred at 50 mA and 100% degradation was achieved in 30 min. While 64% mineralization was achieved with the carbon felt electrode, this value was increased to 77% with CF@MoS_2. As a result, the MoS_2 structure on the cathode surface facilitated the Fe^{3+} / Fe^{2+} cycle and increased vanillin mineralization.

Keywords: Vanillin, Electro-Fenton, Degradation, Mineralization.

Introduction

The fact that drinking water, a resource that is essential for every nation, is running out is concerning. In addition to the unconscious use of drinking water, pollution caused by the mixing of domestic, industrial and agricultural irrigation wastewater continues to threaten clean water resources day by day. These chemicals that enter surface waters may belong to many classes including pharmaceuticals, personal care products, food, dyes and pesticides. Many of these chemicals are refractory organic compounds that are resistant to biological treatment methods. More effective advanced oxidation processes are needed for the oxidation of these pollutants. Advanced oxidation processes (AOPs) have drawn a lot of interest lately as a means of treating refracter organic contaminants. By mineralizing these substances, AOPs can effectively remove them completely while also increasing the solution's biodegradability and lowering toxicity (Scaria et al., 2021; Nidheesh et al., 2022).

The electro-Fenton method has an important place among advanced oxidation methods. The main reason for this is that hydrogen peroxide (H_2O_2) is produced in situ and continuously as a result of the reduction of oxygen at the cathode. Iron (II) ions and H_2O_2 undergo a Fenton reaction, which results in the production of hydroxyl radicals ($^{\bullet}OH$) following (Eqs. (1-2) (Moreira et al., 2017).

$$O_2 + 2e^- + 2H^+ \rightarrow H_2O_2 \quad (1)$$

$$H_2O_2 + Fe^{2+} \rightarrow {}^{\bullet}OH + OH^- + Fe^{3+} \quad (2)$$

Also other transition metals (M^{n+}: Cu^{2+}, Co^{2+}, Mn^{2+} etc.) can catalyze the activation of H_2O_2 to reactive oxygen species, such reactions are called Fenton-like reactions (Brillas et al., 2009).

$$M^{n+} + H_2O_2 + H^+ \rightarrow M^{(n+1)+} + {}^{\bullet}OH + H_2O \quad (3)$$

In the electro-Fenton method, low-cost, physically and chemically durable carbon-based electrodes (carbon felt, fiber, graphite, etc.) are preferred as cathodes. The catalytic amount of Fe(II) ion added to the medium is reduced again at the cathode after the Fenton reaction and participates in the production of hydroxyl radical again.

$$Fe^{3+} + e^- \rightarrow Fe^{2+} \quad (4)$$

The optimum pH value for the electro-Fenton process was determined as 2.8 (Sun and Pignatello, 1993), but the EF process can be properly carried out in the range of $2.5 < pH < 3.5$ (Diagne et al., 2007). High pH values cause precipitation of ferric iron and thus loss of catalyst, while acidic pH values lead to protonation of H_2O_2 and formation of peroxonium ion ($H_3O_2^+$). This ion is electrophilic and does not react with Fe^{2+} and therefore does not form hydroxyl radicals (Feng et al., 2003).

Vanillin is an important flavor and fragrance substance used in both food and cosmetics. Due to its significant consumption, synthetic vanillin is preferred over natural vanillin. In this study, the effectiveness of the cathode material (MoS_2@CF), prepared by loading molybdenum sulfide (MoS_2) onto the carbon felt (CF) electrode surface by hydrothermal method, in the oxidation of vanillin by electro-Fenton method was investigated.

Materials and Methods

Preparation of Molybdenum Sulfide-Carbon Felt Electrode

Molybdenum sulfide (MoS_2) was loaded onto carbon felt and graphite electrodes to form 5% by mass. 0.082 mM ammonium molybdate tetra hydrate and 32.8 mM thiourea were used as precursors in 50 mL of water. This mixture was placed in a stainless steel reactor with a Teflon inner wall and kept at 220 °C for 24 h. The felt was washed with pure water and ethanol and dried (Yang et al., 2021). The synthesized MoS_2 crystal structure was analyzed by XRD (Rigaku Smart Lab, Cu-Kα) and the surface properties of the MoS_2@CF electrode was determined by FE-SEM (Zeiss Supra 55).

Electro-Fenton Experiments

After adding 50 mM Na_2SO_4 to 120 mL of 30 mg/L vanillin solution in a 150 mL capacity glass realtor, the pH was adjusted to 3.0 with 0.3 M H_2SO_4. Finally, 0.2 mM Fe(II) was added to the solution saturated with oxygen gas and a constant current was applied**.** Samples were taken at various times and HPLC and TOC analyses were performed.

Findings and Discussion

The XRD pattern of the synthesized powder MoS_2 structure is given in Figure 1a. The characteristic diffraction patterns of molybdenum disulfide (JCPDS 73-1503) were observed at 14.06°, 33.55°, 39.50° and 59.30° 2θ values, respectively (Ibrahim et al., 2024). SEM images of the molybdenum disulfide loaded carbon felt electrode are given in Figure 1b at different magnifications. MoS_2 crystal structures accumulated on the surface of the carbon felt fibers are seen.

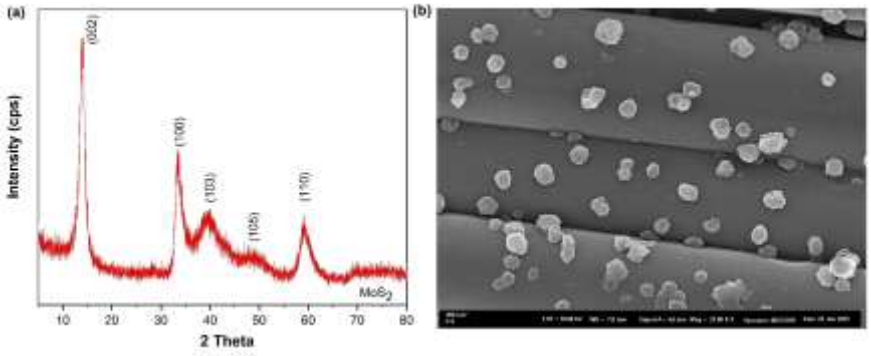


Figure 1. XRD pattern of MoS_2 (a) and Sem image of MoS_2@Cf (b)

After activation of the carbon felt electrode, MoS_2 loading was carried out hydrothermally by targeting 5% by mass. Vanillin degradation and kinetic results are given in Figure 2 using the prepared MoS_2@CF cathode at different currents. When Figure 2a is examined, it is seen that the degradation slows down as the applied current increases. While the degradation of vanillin was completed in approximately 30 min at 50 mA current, 95% was completed in 50 min when the current was increased to 300 mA.

While determining the rate constant of the reaction between vanillin and the hydroxyl radical, pseudo-first-order kinetics is used. According to the equation $-\ln(C_t/C_0) = k_{app}t$, when $-\ln(C_t/C_0)$ is plotted against time (t), the slope of the graph gives the apparent rate constant (Fig. 2b). The apparent rate constant values obtained at different current values in the oxidation of vanillin with MoS_2@CF cathode by the EF method are given in Table 1. Vanillin degradation was carried out at pH 3 with a reaction rate of 0.1220 min^{-1} at 50 mA.

Table 1. Rate constant values with MoS_2@CF cathode at different current values.

	Current (mA)			
	50	**100**	**200**	**300**
k_{app} (min^{-1})	0.1220	0.0905	0.0658	0.0470
R^2	0.9979	0.9972	0.9975	0.9942

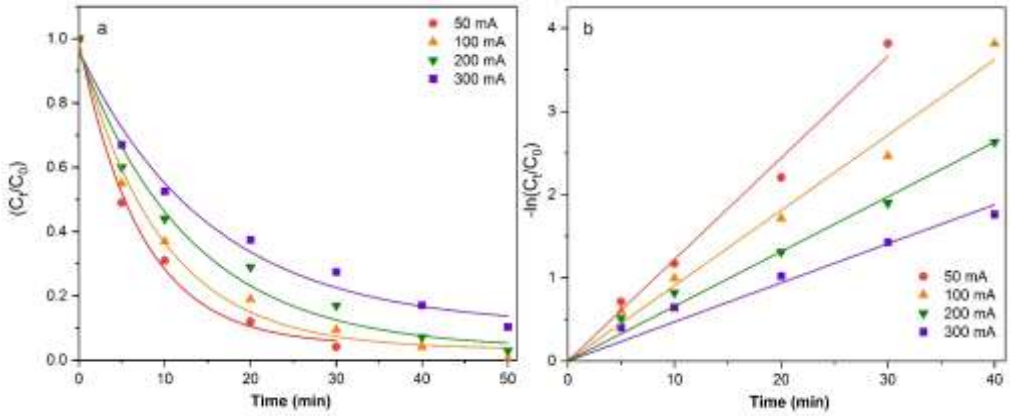


Figure 2. Degradation of vanillin at different current values by electro-Fenton method and MoS_2@CF cathode (a) and kinetics (b) ($[V]_0$= 30 mg/L, $[Fe^{2+}]$= 0,2 mM, $[Na_2SO_4]$= 50 mM, pH 3, V= 120 mL).

Figure 3 shows the vanillin mineralization results at different current densities using the MoS_2@CF cathode, which was prepared by loading MoS_2 onto the carbon felt cathode surface via the hydrothermal method.

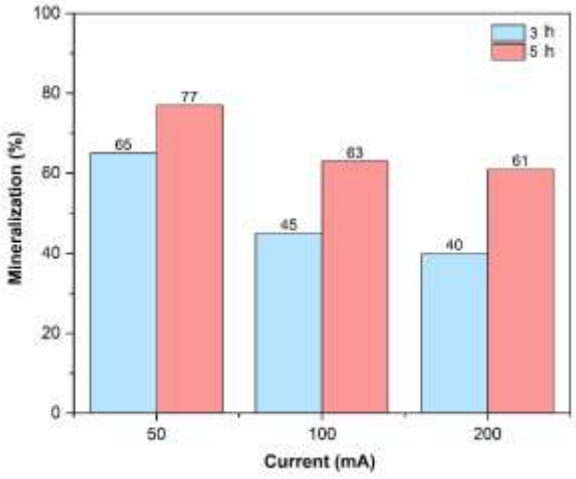


Figure 3. Vanillin mineralization with MoS_2@CF cathode at different current values.

In the EF method performed with a normal felt electrode, 58% and 64% removal was achieved after 3 and 5 h of treatment at 50 mA current, respectively, while this value was obtained as 65% and 77% with the MoS_2 loaded CF. This increase in mineralization is based on the acceleration of the Fe^{III}/Fe^{II} cycle by MoS_2, as stated in the literature (Tian et al., 2023).

Conclusion and Recommendations

In this study, a MoS_2@CF cathode was prepared and characterized, and its effectiveness in the oxidation of the target compound vanillin via the electro-Fenton process was investigated. Compared to the carbon felt (CF) cathode, higher mineralization of vanillin was achieved at pH 3 using the MoS_2@CF cathode through the homogeneous electro-Fenton process. This improvement is attributed to the ability of MoS_2 to accelerate the Fe^{3+}/Fe^{2+} redox cycle

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DETERMINATION OF ABRASION AND SCRATCH RESISTANCE OF PVC, PET AND PMMA

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ABSTRACT

The use of foils as wood-based panel coatings has led to significant advances in technology in this area. Since coating materials are plastic-based, their effects on the environment and human health and their resistance to external effects at the place of use have become an important issue to be investigated. Among artificial coatings, Polyvinyl chloride (PVC), Poly ethylene terephthalate (PET) and Poly methyl methacrylate (PMMA-Acrylic) are widely used. In this study, it was aimed to determine the abrasion and scratch resistance of PVC, PET and PMMA coated on medium density fiberboard (MDF). Abrasion and scratch tests were applied to 3 different surface coatings (PVC, PET, PMMA), 2 different surface types (Glossy-Matte) and 2 different color tones (Light-Dark) prepared in accordance with the principles of TS EN 438-2 and TS EN 15186 (Method B). As a result, the abrasion resistance was the highest (1755 cycles) for PMMA glossy surface light color, and the lowest (10 cycles) for PVC glossy surface dark color, PVC matte surface dark color, PET glossy surface dark color, PET matte surface dark color, PMMA glossy surface dark color and PMMA matte surface dark color. PVC matte surface light color, PVC matte surface dark color, PMMA matte surface light color and PMMA matte surface dark color were found to be more resistant to scratching effects (1.8 N), while PVC glossy surface dark color showed low resistance to scratching resistance (0.4 N). According to these results, PMMA glossy surface light color gave higher values in terms of abrasion resistance, while PVC matte surface light color, PVC matte surface dark color, PMMA matte surface light color and PMMA matte surface dark color gave higher values in terms of scratch resistance.

Keywords: Abrasion resistance, Scratch resistance, PVC, PET, PMMA

PVC, PET VE PMMA'NIN AŞINMA VE ÇİZİLME DİRENCİNİN BELİRLENMESİ

ÖZET

Folyoların ahşap esaslı levha kaplaması olarak kullanımı, bu alandaki teknolojinin büyük ilerleme göstermesine sebep olmuştur. Kaplama malzemeleri, plastik esaslı olması nedeniyle çevre ve insan sağlığına olan etkileri ile kullanım yerinde maruz kaldığı harici etkilere karşı dayanımı araştırılması gereken önemli bir konu haline gelmiştir. Yapay kaplamalar arasında Polivinil klorür (PVC), Poli etilen tereftalat (PET) ve Poli metil metakrilat (PMMA-Akrilik) yaygın olarak kullanılmaktadır.

Bu çalışmada, orta yoğunlukta liflevha (MDF) üzerine kaplanmış PVC, PET ve PMMA'nın aşınma ve çizilme direncinin belirlenmesi amaçlanmıştır. Bu amaca uygun olarak hazırlanan 3 farklı yüzey kaplaması (PVC, PET, PMMA), 2 farklı yüzey çeşidi (Parlak-Mat) ve 2 farklı renk tonu (Açık-Koyu) deney örneklerine TS EN 438-2 ve TS EN 15186 (Metot B) esaslarına uyularak aşınma ve çizilme deneyleri uygulanmıştır. Sonuç olarak aşınma direnci, PMMA parlak yüzeyli açık renkte en yüksek (1755 devir), PVC parlak yüzeyli koyu renk, PVC mat yüzeyli koyu renk, PET parlak yüzeyli koyu renk, PET mat yüzeyli koyu renk, PMMA parlak yüzeyli koyu renk ve PMMA mat yüzeyli koyu renkte en düşük (10 devir) çıkmıştır. PVC mat yüzeyli açık renk, PVC mat yüzeyli koyu renk, PMMA mat yüzeyli açık renk ve PMMA mat yüzeyli koyu renk çizilme etkilerine karşı daha dirençli (1,8 N) bulunurken, PVC parlak yüzeyli koyu renk çizilme direncine karşı düşük direnç (0,4 N) göstermiştir. Bu sonuçlara göre, PMMA parlak yüzeyli açık renk aşınma direnci bakımından, PVC mat yüzeyli açık renk, PVC mat yüzeyli koyu renk, PMMA mat yüzeyli açık renk ve PMMA mat yüzeyli koyu renk çizilme direnci bakımından daha yüksek değerler vermektedir.

Anahtar Kelimeler: Aşınma direnci, Çizilme direnci, PVC, PET, PMMA

1. GİRİŞ

Günümüzde dünya nüfusundaki hızlı artışa paralel olarak yükselen kaliteli ve sağlam mobilya talepleri karşısında, sürekli azalan orman varlıkları ve doğal kaynaklar nedeniyle, mobilya üretiminde masif ağaç malzeme kullanımı ekonomik olmamaktadır. Yıllardır mobilya sektörünün ana maddesini ahşap ve ahşap esaslı levhalar oluşturmaktadır. Ancak, son yıllarda, gelişen teknoloji mobilya sektöründe farklı ana hammaddelerin kullanılmasına imkân vermiştir. Özellikle polivinilklörür (PVC) levhalar, düzgün ve sert bir yapıya sahip, suya ve neme karşı dayanıklı, asit, alkaliler, hidrolik yağlar gibi aşındırıcı maddelere karşı yüksek dirençli, farklı renklere boyanabilmesi, laminat ile kaplanabilmesi v.b. özelliklerinden dolayı iç dekorasyon ve mobilya üretiminde kullanılmaya başlanmıştır. Suya ve neme karşı dayanıklı olduklarından dolayı mutfak, banyo, wc gibi ortamlardaki mobilyaların yapımında kullanılabilir (Bayındır, 2009).

MDF'nin yüzeyi genellikle laminasyon, kaplama veya vernikleme ile tamamlanır. Her türlü yüzey kaplaması gerekli kaliteyi sağlamalıdır. Kalite, yüzey kaplamanın özelliklerine göre değerlendirilir. Kaplama malzemeleri veya folyolar tarafından oluşturulan yüzey kaplamaları görünüm, fiziksel-mekanik özellikler ve kimyasal direnç özelliklerine göre değerlendirilmiştir (Tesařová ve ark, 2010; Scrinzi, ve ark, 2011; Modrák ve Mandulák, 2013; Bekhta ve ark, 2014; Salca ve ark, 2017; Yong ve ark., 2017).

MDF için laminasyon, kaplama ve vernikleme dışında, PET, PMMA, PVC-PET, emprenyeli kağıt, boya ve laminatta yüzey kaplaması olarak yaygın şekilde kullanılmaktadır.

Lake boyalı, PVC ve melamin kaplı MDF levhalarla yapılan bir çalışmada aşınma mukavemetlerinin birbirinden farklı olduğu görülmüştür. Standartta istenen değer 150 devir olup, elde edilen sonuçların standartlara uygun olduğu görülmüştür. En iyi aşınma mukavemeti PVC kaplı levhalarda bulunmuştur. Bunu melamin ve lake boya kaplı levhalar takip etmiştir. Yapılan benzer bir çalışmada aşınma mukavemeti melamin kaplı yüzeylerde en iyi 200 devir, lake boyalı yüzeylerde 180 devir bulunmuştur (Aksu 2009; Özdemir ve Malkoçoğlu 2010). Buna göre lake boyalı, PVC ve melamin kaplı yüzeylerin aşınma mukavemetleri standartların üstünde olduğu görülmüştür (Muğla, 2010).

Aynı çalışma içerisinde, lake boyalı yüzeylerin çizilme mukavemeti standart değerlerden düşük bulunmuştur. Buna karşılık PVC kaplı levhaların çizilme mukavemeti yüksek bulunmuştur. Melamin kaplı yüzeylerin standart değerlerde olduğu görülmüştür. İstek ve ark, (2010) tarafından yapılan çalışmada melamin kaplı MDF levhaların çizilme mukavemeti değeri 4 N bulunmuştur (Muğla, 2010).

Mobilya kapı yüzey kalitesinin değerlendirilmesiyle ilgili bir çalışmada, MDF kapılarda PVC folyo (parlak ve mat), akrilik folyo ve PUR pigmentli kaplama malzemesinin bazı özellikleri test edilmiştir. Yüzeylerin film sertliği, darbe direnci ve çizilmeye karşı direnç özellikleri değerlendirilmiştir. Poliüretan yüzey kaplaması ve parlak PVC folyo aynı film sertliğine ulaşmıştır. Poliüretan kaplamanın darbe direnci, PVC folyoların ve akrilik folyonun darbe direncinden önemli ölçüde daha düşük olduğu bildirilmiştir. Poliüretan kaplamanın çizilmeye karşı direnci, folyolu yüzeylerle karşılaştırıldığında daha düşük olduğu belirtilmiştir (Gabriela vd., 2019).

ABS ve PMMA levhaları sol-jel tekniğiyle kaplayarak asınma, çizilme, kimyasal ve ısıya dayanıklı hale getirmek amacı ile yapılan çalışmada, perfloro alkolden yola çıkılarak alkoksisilan sonlu üretan akrilat fonksiyonlu oligomer sentezlenerek sol-jel yöntemi ile hazırlanan organikinorganik hibrid kaplama formülasyonları ABS ve PMMA levhalara uygulanmış ve UV ısınlarının etkisiyle sertlestirilmiştir. Çalışma sonuçlarına göre, yapılan

uygulamanın ABS ve PMMA levhaların asınma, çizilme, ısı ve kimyasallara karsı dayanımı artırdığı bildirilmiştir. (Kartal, 2009).

Melamin emdirilmiş kağıtlar (MIP), poliüretan esaslı vernik (PV), poliüretan esaslı lake boya (LP), sürekli pres laminatlar (CPL), yüksek basınçlı laminatlar (IIPL) ve polivinilklorür levhalar (PVC) yonga levha için yüzey kaplama malzemesi olarak kullanılmış, bu yüzey kaplama malzemelerinde çizilme (SR), aşınma (AR), sigara yanıkları ve lekelenmeye karşı direnç özellikleri araştırılmıştır. Sonuçlar, çizilme ve aşınma dirençlerinin kaplama tiplerinden önemli ölçüde etkilendiğini göstermiştir. Yüksek basınçlı ve sürekli pres laminatlar lekelenmeye ve yanmaya karşı dirençli olup en yüksek aşınma ve çizilme direnci değerlerine sahip olduğu görülmüştür. En yüksek aşınma dirençleri HPL, CPL, PVC, LP ve MIP sıralamasında bulunurken, PV'nin en düşük değere sahip olduğu bildirilmiştir. Bu, kaplamaların reçine tipi, kullanılan miktar ve üretim koşullarındaki farklılıklardan kaynaklanma ihtimali olabileceği söylenmiştir. En yüksek çizilme dirençleri HPL, CPL, PVC, MIP, PV sırasında bulunurken, LP'nin en düşük değere sahip olduğu, bunun nedeninin kaplama üretiminde kullanılan reçinedeki fark olduğu bildirilmiştir (Özdemir vd., 2014).

Bu çalışmada, Orta yoğunlukta lif levha (MDF) üzerine kaplanmış, Poli vinil klorür (PVC), Poli etilen tereftalat (PET) ve Poli metil metakrilat (PMMA) malzemelerin, aşınma ve çizilme dirençlerine karşı performanslarının karşılaştırılması amaçlanmıştır.

2. MALZEME VE YÖNTEM

2.1. Malzeme

Bu çalışmada 18 mm kalınlığında MDF yüzeyine PVC, PET ve PMMA kaplanmış folyolar kullanılmıştır (Resim 1). Kullanılan deney numuneleri iki ayrı ticari işletmeden temin edilmiştir.



Resim 1. PVC-PET-PMMA kaplanmış deney örnekleri

2.1.1. Deney Örneklerinin Hazırlanması

2.1.1.1. Aşınma Direnci

Aşınma direnci örnekleri TS EN 438-2 esaslarına göre hazırlanmıştır. Bu amaçla, her grup için 100x100 mm boyutlarında 10'ar adet olmak üzere toplam 120 (12x10) adet örnek hazırlanarak merkezlerine 6 mm çapında delik açılmıştır.

Çalışmada kullanılan deney numuneleri ilgili standartlarda belirtilen ölçü ve sayılarda hazırlanmıştır. Deney örnekleri 23 ± 2 ºC sıcaklık ve %50 ± 5 bağıl nem şartlarında değişmez kütleye ulaşıncaya kadar bekletilmiştir.

Testler Türk Standartları Enstitüsü Yapı Malzemeleri Laboratuvarı Ahşap ve Mobilya Bölümü'nde, TABER test cihazında gerçekleştirilmiştir (Resim 2).

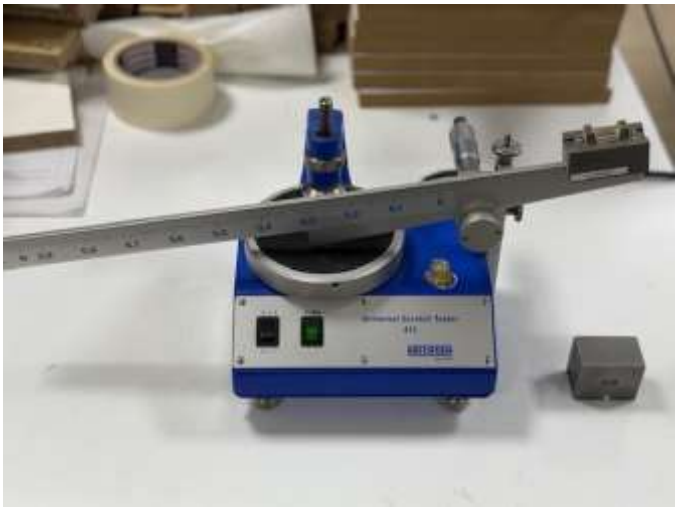


Resim 2. Taber aşındırma test cihazı

2.1.1.2. Çizilme Direnci

Çizilme direnci örnekleri TS EN 15186 (Metot B) esaslarına göre hazırlanmıştır. Bu amaçla, her grup için 100x100 mm boyutlarında 10'ar adet olmak üzere toplam 120 (12x10) adet örnek hazırlanarak merkezlerine 6,5 mm çapında delik açılmıştır.

Testler Türk Standartları Enstitüsü Yapı Malzemeleri Laboratuvarı Ahşap ve Mobilya Bölümü'nde ERICHSEN test cihazında gerçekleştirilmiştir (Resim 3).



Resim 3. Erichsen çizilme test cihazı

Deney örnekleri tablo 1'de verilmiştir.

Tablo 1. Malzeme çeşidi

Malzeme Çeşidi	Deney Çeşidi		Toplam (Adet)
	Aşınma	Çizilme	
PVC-Parlak-Açık Renk	10	10	20
PVC-Parlak-Koyu Renk	10	10	20
PVC-Mat-Açık Renk	10	10	20
PVC-Mat-Koyu Renk	10	10	20
PET-Parlak-Açık Renk	10	10	20
PET-Parlak-Koyu Renk	10	10	20
PET-Mat-Açık Renk	10	10	20
PET-Mat-Koyu Renk	10	10	20
PMMA-Parlak-Açık Renk	10	10	20
PMMA-Parlak-Koyu Renk	10	10	20
PMMA-Mat-Açık Renk	10	10	20
PMMA-Mat-Koyu Renk	10	10	20
Toplam	**120**	**120**	**240**

2.2. Yöntem

2.2.1. Aşınma Direnci

Aşınma direnci, TS EN 438-2 esaslarına uyularak aşındırma deneyi cihazında belirlenmiştir (Resim 2). Buna göre; aşındırıcı tanecikleri alüminyum oksit olan zımpara kağıdı ve deney örnekleri 23 ± 2 ºC sıcaklık ve %50 ± 5 bağıl nem şartlarında 72 saat bekletildikten sonra zımpara tekerleklerin üzerine yapıştırılmıştır. Örnek, yatay düzleme paralel 58-62 dev/dak hızla dönen disk üzerine bağlanarak deneye başlanmış ve her 500 devirde zımpara değiştirilmiştir. Deneyin başında, aşınma için her 25 devirden sonra numune kontrol edilmiştir. Aşınma noktasına (İN) yaklaşırken, değerlendirme her 10 devirde bir yapılmıştır. Deneye, ilk aşınma noktasına (İN) ulaşıncaya kadar aynı şekilde devam ettirilmiştir. İlk aşınma noktası (İN), baskının, desenin veya düz rengin ilk net olarak algılanabilir aşınmasının ortaya çıktığı ve alt tabakanın 3/4'ü görünür hale geldiği noktadır.

2.2.2. Çizilme Direnci

Çizilme direnci TS EN 15186 (Metot B) esaslarına göre çizilme deneyi cihazında belirlenmiştir (Resim 3). Buna göre; hazırlanan örnekler 23 ± 2 ºC sıcaklık ve %50 ± 5 bağıl nem şartlarında değişmez kütleye gelinceye kadar bekletilmiştir. Deney cihazı, su terazisi yardımıyla yer düzlemine paralel konuma getirilerek deney örneği 5 ± 1 dev/dak hızla dönen destek tablası üzerine sıkıştırma vidası yardımıyla bağlanarak, yarıçapı 0,090 ± 0,003 mm olan elmas ucu

taşıyan destek kolu elmas uç örneğe temas ettiğinde yatay konuma getirilmiş ve ± 0,01 duyarlıkla ağırlık ayarları yapılmıştır.

Deneye 5 N'luk kuvvet uygulanarak başlanmış, örnek yüzeyinde görünür iz oluşmadığı taktirde yük 0,5 N'luk kademelerle kesintisiz çizik meydana gelinceye kadar artırılmıştır. 5 N'luk kuvvet uygulandığında kesintisiz çizik oluştuğu taktirde; kuvvet 2 N'a kadar 0,5 N'luk, 1 N'a kadar 0,20 N'luk, 1 N'un altında 0,1 N'luk kademelerle azaltılmış, kesik çizgiler meydana geldiğinde deneye son verilmiştir.

Örnekler testten sonra 24 saat süreyle 23 ± 2 oC sıcaklık ve %50 ± 5 bağıl nem şartlarında bekletilmiştir.

Örnek yüzeyi temiz bir bezle temizlendikten sonra 1200 ± 200 lümen bir ışık altında yaklaşık 400 ± 10 mm mesafeden çıplak gözle bakılarak test yüzeyi şablonunun 6 yuvasında tam görünür çizik izine yol açan minimum yük, örneğin çizilme direnci değeri olarak kaydedilmiştir.

3. BULGULAR

3.1. Aşınma Direnci

Deney numunelerinin aşınma direnç değerleri Tablo 2'de verilmiştir.

Tablo 2. Aşınma direnci değerleri

Yüzey Kaplama Malzemesi	Aşınma Direnci (Devir)				
	X_{min}	X_{max}	$\bar{x}$	D_g	S
PVC-Parlak-Açık Renk	1450	1650	1530	200	58,69
PVC-Parlak-Koyu Renk	10	10	10	0	0,00
PVC-Mat-Açık Renk	1050	1150	1070	100	48,30
PVC-Mat-Koyu Renk	10	10	10	0	0,00
PET-Parlak-Açık Renk	15	15	15	0	0,00
PET-Parlak-Koyu Renk	10	10	10	0	0,00
PET-Mat-Açık Renk	1500	1750	1665	250	66,87
PET-Mat-Koyu Renk	10	10	10	0	0,00
PMMA-Parlak-Açık Renk	1700	1850	1755	150	49,72
PMMA-Parlak-Koyu Renk	10	10	10	0	0,00
PMMA-Mat-Açık Renk	700	800	735	100	33,75
PMMA-Mat-Koyu Renk	10	10	10	0	0,00

X_{min}: Mininum değer X_{max}: Maksimum değer $\bar{x}$: Aritmetik ortalama

D_g: Değişim genişliği S: Standart sapma

Aşınma direnci en yüksek (1755 devir) PMMA parlak yüzeyli açık renkte, en düşük (10 devir) PVC parlak yüzeyli koyu renk, PVC mat yüzeyli koyu renk, PET parlak yüzeyli koyu renk, PET mat yüzeyli koyu renk, PMMA parlak yüzeyli koyu renk ve PMMA mat yüzeyli koyu renkte çıkmıştır.

3.2. Çizilme Direnci

Deney numunelerinin çizilme direnç değerleri Tablo 3'te verilmiştir.

Tablo 3. Çizilme direnci değerleri (N)

Yüzey Kaplama Malzemesi	Çizilme Direnci (N)				
	X_{min}	X_{max}	$\bar{x}$	D_g	S
PVC-Parlak-Açık Renk	0,5	0,5	0,5	0	0,00
PVC-Parlak-Koyu Renk	0,4	0,4	0,4	0	0,00
PVC-Mat-Açık Renk	1,6	1,8	1,8	0,2	0,08
PVC-Mat-Koyu Renk	1,6	1,8	1,8	0,2	0,08
PET-Parlak-Açık Renk	0,5	0,5	0,5	0	0,00
PET-Parlak-Koyu Renk	0,5	0,5	0,5	0	0,00
PET-Mat-Açık Renk	1,4	1,4	1,4	0	0,00
PET-Mat-Koyu Renk	1,4	1,6	1,6	0,2	0,06
PMMA-Parlak-Açık Renk	0,7	0,7	0,7	0	0,00
PMMA-Parlak-Koyu Renk	0,6	0,6	0,6	0	0,00
PMMA-Mat-Açık Renk	1,8	1,8	1,8	0	0,00
PMMA-Mat-Koyu Renk	1,6	1,8	1,8	0,2	0,08

X_{min}: Mininum değer X_{max}: Maksimum değer $\bar{x}$: Aritmetik ortalama

D_g: Değişim genişliği S: Standart sapma

PVC mat yüzeyli açık renk, PVC mat yüzeyli koyu renk, PMMA mat yüzeyli açık renk ve PMMA mat yüzeyli koyu renk çizilme etkilerine karşı daha dirençli (1,8 N) bulunurken PVC parlak yüzeyli koyu renk çizilme direncine karşı düşük direnç (0,4 N) göstermiştir.

4. SONUÇLAR VE TARTIŞMA

Aşınma direnci, en yüksek PMMA parlak yüzeyli açık renkte (1755 devir), en düşük ise PVC parlak yüzeyli koyu renk, PVC mat yüzeyli koyu renk, PET parlak yüzeyli koyu renk, PET mat yüzeyli koyu renk, PMMA parlak yüzeyli koyu renk ve PMMA mat yüzeyli koyu renkte (10 devir) çıkmıştır.

Aşınma direncinin koyu renkli örneklerde düşük (10 devir) çıkmasının en önemli nedeninin, açık renkler ile mukayese edildiğinde, yüzey bozunumunun (aşınma) koyu örneklerde gözlemsel olarak daha belirgin olmasından kaynaklandığı düşünülmektedir. Koyu renkli deney örneklerinde aşındırma işlemi başladığı ilk birkaç devirden sonra aşınan kısımlarda oluşan matlaşma ve renk kaybı açık renkli örneklerde 2000'li devir sayılarında gözlenmiştir.

Benzer durum, çizilme direncinde de etkili olmuş ve en yüksek değerler PVC mat yüzeyli açık renk, PVC mat yüzeyli koyu renk, PMMA mat yüzeyli açık renk ve PMMA mat yüzeyli koyu renkte (1,8 N) elde edilmiş, en düşük değerler ise PVC parlak yüzeyli koyu renkte (0,4 N) çıkmıştır.

Çizilme direncinde düşük direnç gösteren deney örnekleri genelde parlak yüzeyli olup, çizilmeyi açık bir şekilde yansıtmaktadır. Mat yüzeylerde belirginlik daha düşük seviyededir. Bu nedenle, aşınma ve çizilme direncinin yüksek olması istenilen durumlarda ve açık renkli yüzey kaplama malzemelerinin tercih edilmesi önerilebilir.

5. TEŞEKKÜR VE BİLGİ NOTU

Deneysel çalışmalarımızda yardımcı olan TSE Teknik Şefi Orm. End. Müh. Hasan AKSU'ya teşekkürü borç biliriz.

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THE USE OF CLAY AS A SUSTAINABLE DYESTUFF IN TEXTILES

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ABSTRACT

The structural properties of clay and its potential in the textile dyeing process are addressed. In terms of usage, clays meet fundamental human needs and hold significant economic potential across various industrial sectors. As a sustainable alternative to harmful washing processes, trials with clay materials found in our country should be conducted to integrate them into the textile industry. This would reduce the consumption of water, energy, and chemicals, thereby providing environmental benefits. As an alternative to the environmental impacts caused by the high water and chemical usage of the textile industry, various types of clay have been evaluated as natural dyeing agents. In this context, fabrics made of natural fibers such as cotton, wool, linen, and hemp were prepared for dyeing using appropriate mordanting techniques, and an experimental study was conducted by dyeing them with different types of clay. The resulting fabrics were subjected to tests for colour fastness to rubbing and washing. Based on the data obtained, the clay-dyed fabrics were evaluated within the framework of sustainable design principles, and a collection made from these fabrics was prepared. The research demonstrates that clay dyeing can significantly reduce water, energy, and chemical consumption in the textile sector and contribute to sustainable production using natural materials. The collection developed as a result presents an alternative method for ecological textiles.

Keywords: Ecological Textile, Sustainable Fashion, Textile and Design, Natural Textile Dyeing

KİLİN TEKSTİLDE SÜRDÜRÜLEBİLİR BOYAR MADDE OLARAK KULLANIMI

ÖZET

Kilin yapısal özellikleri ve tekstil boyama sürecindeki potansiyeli ele alınmıştır. Killer kullanım açısından, birçok endüstriyel alanda büyük ekonomik potansiyel oluşturarak insanlığın temel ihtiyaçlarını karşılamaktadır. Zararlı yıkama süreçlerine sürdürülebilir bir yaklaşım olarak, ülkemizde bulunan kil malzemeleri ile denemeler yapılarak tekstil sektörüne kazandırılmalıdır. Böylece su, enerji ve kimyasalların kullanımı en aza indirilerek fayda sağlanır. Tekstil endüstrisinin yüksek su tüketimi ve kimyasal kullanımından kaynaklanan çevresel etkilerini azaltmaya yönelik bir alternatif olarak, farklı kil türleri doğal boyar madde olarak değerlendirilmiştir. Bu kapsamda, doğal liflerden oluşan pamuk, yün, keten ve kenevir kumaşları uygun mordanlama teknikleriyle boyamaya hazırlanmış ve çeşitli kil türleriyle boyanarak deneysel bir çalışma yürütülmüştür. Uygulanan yöntemler sonucunda elde edilen kumaşlar sürtünmeye karşı renk haslığı ve yıkama haslığı ve testlerine tabi tutulmuştur. Elde edilen veriler doğrultusunda, kil ile boyanmış kumaşlar sürdürülebilir tasarım ilkeleri çerçevesinde değerlendirilmiş ve bu kumaşlardan oluşan bir koleksiyon hazırlanmıştır. Araştırma, kil boyamanın tekstil sektöründe su, enerji ve kimyasal tüketimini önemli ölçüde azaltabileceğini ve doğal malzemelerle sürdürülebilir üretime katkı sağlayabileceğini ortaya koymaktadır. Sonuçlar doğrultusunda geliştirilen koleksiyon, ekolojik tekstiller için alternatif bir yöntem sunmaktadır.

Anahtar Kelimeler: Ekolojik Tekstil, Sürdürülebilir Moda, Tekstil ve Tasarım, Doğal Tekstil Boyama

GİRİŞ

Sanayi devriminden günümüze kadar hızla büyüyen tekstil sektörü, sürdürülebilir üretim teknikleri arayışında doğal kaynaklara yönelmektedir. Bu bağlamda, talebi giderek artan hammaddelerden biri de kildir. Mineral yapıları, renkleri ve kimyasal içerikleri bakımından çeşitlilik gösteren killer, farklı endüstrilerde yaygın olarak kullanılmaktadır. Dünya genelinde yaklaşık 70 milyar ton kil rezervi bulunurken, Türkiye'de bu miktar 39 milyon ton olarak belirlenmiş ve yıllık üretim kapasitesi 900.000 tona ulaşmıştır. Günümüzde, dünya çapında üretilen kilin yaklaşık %75'i cam, kozmetik, inşaat, porselen, seramik ve tekstil gibi sektörlerde değerlendirilmektedir. (Maden Tetkik ve Arama Genel Müdürlüğü, t.y.). Tekstil endüstrisi, küresel su kirliliğinin yaklaşık %20'sinden sorumludur. Geleneksel boyama ve yıkama süreçleri, yüksek miktarda su ve kimyasal tüketimi gerektirdiği için çevresel sorunlara yol açmaktadır. Özellikle denim üretiminde kullanılan taş yıkama, ağır metaller içeren boyalar ve endüstriyel kimyasallar su kaynaklarını kirletmekte, işçi sağlığını tehdit etmekte ve ekolojik dengeyi bozmaktadır. Alternatif olarak, doğal boyama yöntemlerinin geliştirilmesi ve kullanımının yaygınlaştırılması, çevresel etkinin azaltılmasına katkı sağlayabilir.

Bu çalışmada, Türkiye'de bulunan farklı kil türlerinin tekstil boyama süreçlerinde kullanım potansiyeli araştırılmış ve deneysel uygulamalar gerçekleştirilmiştir. Boyama sürecinde, pamuk, keten ve kenevir kumaşlar tercih edilmiştir. Elde edilen kumaşlar sürdürülebilirlik ve tasarımsal özellikler açısından değerlendirilmiş, sonuç olarak bir koleksiyon oluşturulmuştur. Araştırma, kil boyamanın tekstil sektöründe su, enerji ve kimyasal kullanımını önemli ölçüde azaltarak çevre dostu bir alternatif sunduğunu ortaya koymaktadır. Türkiye'nin sahip olduğu geniş kil rezervlerinin bu alanda değerlendirilmesi, sürdürülebilir tekstil üretimi açısından büyük bir potansiyele sahiptir.

MATERYAL VE YÖNTEM

Bu çalışmada, doğal boyama süreçlerinde kilin etkisini incelemek amacıyla deneysel bir araştırma yürütülmüştür. Araştırma kapsamında, doğal liflerden oluşan kumaşlar (pamuk, keten, yün ve kenevir) farklı kil türleri ile boyanmıştır. Doğal boyama sürecinde hem doğal boyar maddeler hem de çeşitli yardımcı maddeler kullanılmıştır. Mordanlama işlemlerinde, boyanın liflere daha iyi tutunmasını sağlamak amacıyla şap (alüminyum sülfat) ve krem tartar (potasyum bitartrat) tercih edilmiştir. Boyama sonrası renk sabitleyici olarak sirke (asetik asit) kullanılmıştır. Boyar madde olarak doğal kil çeşitlerinden yararlanılmıştır. Yeşil kil, kırmızı kil ve siyah kil ana boyar maddeler olarak kullanılmış; ayrıca siyah ve kırmızı kil belirli oranlarda karıştırılarak kahverengi ton elde edilmiştir.

Doğal kil boyalarıyla renklendirilmiş dört farklı kumaş (pamuk, yün, keten ve kenevir) seçilmiş ve bu kumaşlara yeşil, kırmızı, siyah ve kahverengi kil pigmentleri ile doğal boyama işlemi uygulanmıştır. Boyama sonrasında, kumaş örnekleri sürtme (kuru ve yaş), yıkama haslığı ve multifiber bezle lekeleme gibi standart renk haslığı testlerine tabi tutulmuştur. Testlerde, renk değişimi ve boyanın diğer yüzeylere geçişi değerlendirilmiş; süreç boyunca tüm aşamalar görsel ve sayısal verilerle belgelenmiştir. Elde edilen bulgular, doğal kil boyalarının farklı kumaş yüzeylerindeki dayanıklılığını karşılaştırmalı olarak incelemek üzere analiz edilmiştir. Boyama sonrası kumaşlara renk haslığı, yıkama dayanıklılığı ve ışık dayanıklılığı testleri uygulanmıştır. Çalışma kapsamında ayrıca kil boyama tekniği ile üretilen kumaşlar sürdürülebilir tasarım ilkeleri doğrultusunda değerlendirilmiş ve bir koleksiyon oluşturulmuştur

BULGULAR VE TARTIŞMA

Araştırma süreci boyunca kil boyama uygulamaları, sistematik bir şekilde deneysel olarak gerçekleştirilmiştir. Bu kapsamda, doğrudan üretim aşamasına geçilmeden önce çeşitli ön denemeler yapılmıştır. İnternette yer alan kil boyama yöntemleri ve prosesleri incelenerek, farklı oranlar ve teknikler denenmiş; bu ön denemeler sonucunda en verimli sonuç alınan boyama prosesi belirlenmiştir. Bu denemeler sırasında elde edilen ara sonuçlara ait görseller sunulmuştur.

Belirlenen uygun proses doğrultusunda, dört farklı doğal elyaf (pamuk, keten, kenevir, yün) ön işlemlerle boyamaya hazırlanmış ve kil boyama işlemine tabi tutulmuştur. Uygulanan boyama süreci; mordanlama, boyama ve fiksaj aşamalarını içermektedir.

Boyama işlemi sonrasında kumaşlar iki farklı doğrultuda değerlendirilmiştir. Birinci grup kumaşlar, tasarımsal uygulamalarda değerlendirilmiş ve bu doğrultuda dört parçadan oluşan bir kıyafet koleksiyonu oluşturulmuştur. İkinci grup kumaşlar ise belirli testlere tabi tutularak kil boyamanın dayanıklılığı, renk tutuculuğu ve kumaş yüzeyine etkisi analiz edilmiştir.

Kil boyama uygulamasına geçilmeden önce, literatür taramaları ve mevcut doğal boyama tekniklerinin incelenmesi doğrultusunda çeşitli ön denemeler gerçekleştirilmiştir. Bu denemeler, kullanılacak boyar maddelerin ve yardımcı kimyasalların kumaş üzerindeki etkilerinin değerlendirilmesi ve uygulanacak nihai yöntemlerin belirlenmesi açısından büyük önem taşımıştır. Deneme süreci; oranların, uygulama yöntemlerinin ve bekletme sürelerinin kumaş üzerindeki etkilerini gözlemlemeye yönelik sistematik bir çalışma şeklinde yürütülmüştür.

BOYAMA SÜREÇLERİ VE AŞAMALARI

1.Mordanlama İşlemi

Boya işlemi öncesinde kumaşlar mordanlanarak boyanın liflere daha iyi tutunması sağlanmıştır (Görsel 1). Deneme numunelerinden elde edilen verilere dayanarak, mordanlama maddelerinin konsantrasyonu iki katına çıkarılmıştır. Kullanılan mordan maddeleri ve oranları aşağıdaki gibidir:

- Şap: Kumaş ağırlığının %20’si
- Krem tartar: Kumaş ağırlığının %16’sı

Çalışmada kullanılan kumaşlar ve ağırlıkları:

- Pamuk: 42 g
- Kenevir: 57,1 g
- Keten: 41,7 g
- Yün: 15 g

Toplam kumaş ağırlığına göre hesaplanan mordan miktarları:

- Şap: 31,16 g
- Krem tartar: 24,93 g



Görsel 1. Mordanlama aşaması



Görsel 2. Mordanlama işlemi sonrası kumaşlar

Mordan çözeltisi hazırlanırken, kumaşları tamamen kaplayacak miktarda su kullanılmış ve suyun sıcaklığı 40-50°C aralığında tutulmuştur. Kumaşlar çözeltide 40 dakika boyunca bekletilmiş, ardından doğal ortamda kurumaya bırakılmıştır.

2. Doğal Boyama İşlemi

Her renk için 500 g kil kullanılarak doğal boya çözeltileri hazırlanmıştır. Kullanılan renkler ve malzemeler:

- Yeşil: 500 g yeşil kil
- Kırmızı: 500 g kırmızı kil

- Siyah: 500 g siyah kil
- Kahverengi: 250 g kırmızı kil + 250 g siyah kil



Görsel 3. Oluşturulmuş boya çözeltisi

Her boya çözeltisi 2 litre su içinde hazırlanmış ve kumaşlar bu çözeltilerde 40-45 dakika boyunca bekletilmiştir (Görsel 3). Boyama süresince, kumaşların daha homojen renk almasını sağlamak amacıyla el ile karıştırma işlemi yapılmıştır. Boyama işlemi tamamlandıktan sonra kumaşlar sıkılarak doğal ortamda kurumaya bırakılmıştır.



Görsel 4. Boyama işlemi sonrası kumaşlar

3. Fikseleme İşlemi

Boyama sonrası renklerin kalıcılığını artırmak amacıyla sirke ile fikseleme işlemi uygulanmıştır. Kullanılan sirke miktarı kumaş ağırlığının %10'u olacak şekilde belirlenmiştir.

Kumaşlara göre kullanılan sirke miktarları:

- Kırmızı kumaş: 28,2 ml
- Siyah kumaş: 32 ml
- Kahverengi kumaş: 76,8 ml

- Yeşil kumaş: 86,6 ml

Fikseleme işlemi sırasında suyun sıcaklığı 60-70°C arasında tutulmuş, sıcaklığın 70°C'yi aşmamasına özen gösterilmiştir. Kumaşlar 25 dakika boyunca fikseleme banyosunda bekletilmiş, ardından tekrar doğal ortamda kurumaya bırakılmıştır (Görsel 5).

4. Su Miktarları

Fikseleme banyosunda kullanılan su miktarları kumaş türüne göre ayarlanmıştır:

- Yün kumaşı: 2 litre
- Keten ve kenevir kumaşı: 3 litre
- Pamuk kumaşı: 4 litre



Görsel 5. Boyama sonrası fikseleme aşaması

TESTLER VE ANALİZLER

Bu çalışmada, doğal kil boyalarıyla renklendirilmiş dört farklı tekstil yüzeyine uygulanan renk haslığı testleri ele alınmıştır. Kullanılan kumaş örnekleri; yeşil kil ile boyanmış pamuk kumaşı, kırmızı kil ile boyanmış yün kumaşı, siyah kil ile boyanmış keten kumaşı ve kırmızı ile siyah kilin karıştırılmasıyla elde edilen kahverengi kil ile boyanmış kenevir kumaşından oluşmaktadır. Her biri doğal içerikli bu boyalarla renklendirilmiş kumaşlara, kullanım esnasında karşılaşılabilecek fiziksel koşullara karşı renk dayanıklılıklarının belirlenebilmesi amacıyla çeşitli haslık testleri uygulanmıştır.



Görsel 6. Sürtme cihazı

İlk olarak, söz konusu dört kumaş örneği kuru ve yaş sürtme testine tabi tutulmuştur (Görsel 6). Test öncesinde kumaşlar, ilgili standarda uygun ölçülerde kesilmiş ve hem kuru hem yaş sürtme testleri için ayrı ayrı hazırlanmıştır. Testler sonucunda, kumaş yüzeyinden sürtme kumaşına geçen boya miktarı değerlendirilerek, renk haslığına dair veriler elde edilmiştir (Görsel 7).



Görsel 7. Kuru ve yaş sürtme sonrası kumaş parçaları

Ardından, boyalı kumaşların yıkama haslığı incelenmiştir. Bu test için, her bir boyalı kumaş örneği, üst ve alt kısımlarda yer alan refekat bezi arasına dikilmiştir (Görsel 8). Böylelikle test süreci sırasında boyalı kumaşın multifiber bezle doğrudan temas etmesi sağlanmıştır.



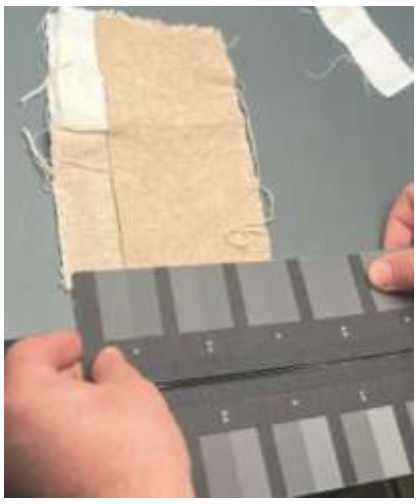
Görsel 8. Yıkama haslığı testleri için hazırlanan kumaşlar

Hazırlanan kumaş parçaları paslanmaz çelik bilyeler, multifiber, standartta belirtilen yıkama deterjanı ile birlikte kaplara yerleştirilir (Görsel 9). Testin amacı yapılan numunenin yıkama sonrası ne kadar solduğu ya da ne kadar renk kaybettiği ve kaybedilen rengin refakat bezini ne kadar derecede kirlettiğinin eldesidir. Seçilen yıkamaya göre yıkama haslığı test edilir. Daha sonra yapılacak kurutma işleminden sonra test numunesinin rengindeki değişme ve refakat bezlerine solma ve lekeleme olarak gri skala ile değerlendirilir (Görsel 10).



Görsel 9. Yıkama haslığı için hazırlanan kumaşlar

Tüm bu test aşamaları, görsel kayıtlarla da desteklenmiş; kumaşların kesilme anları, metal kaplara yerleştirilmeleri ve test sonrasındaki durumları fotoğraflanarak belgelenmiştir. Son aşamada, kumaşlar ışık altında incelenerek görsel renk değişimleri değerlendirilmiş, bu incelemeler de rapora dâhil edilmiştir. Elde edilen veriler doğrultusunda, kil bazlı doğal boyaların farklı kumaş türleri üzerindeki haslık performansları karşılaştırmalı olarak analiz edilmiştir.



Görsel 10. Kumaşların değerlendirme aşaması

Bu çalışmada, dört farklı doğal kumaş (pamuk, keten, kenevir ve yün) üzerinde doğal boyama yöntemleri uygulanmıştır. Her bir kumaş yalnızca bir doğal renklendirici ile boyanarak dört ayrı numune elde edilmiştir. Numuneler, boyama sonrası gerçekleştirilen test ve analizlerin doğru ve sistematik bir şekilde yürütülebilmesi amacıyla özel kumaş kodları ile tanımlanmıştır. Kodlama sistemi hem kumaşın cinsini hem de uygulanan rengi temsil edecek şekilde oluşturulmuş olup, olası karışıklıkların önüne geçmeyi hedeflemektedir. Ta ilgili numunelerin kumaş türü ve renk bilgilerini içermektedir.

Tablo 1. İlgili numunelerin kod, kumaş türleri ve renk bilgileri

Kumaş Kodu	Kumaş Rengi	Kumaş cinsi
Y-P	YEŞİL	PAMUK
K-Y	KIRMIZI	YÜN
S-KT	SİYAH	KETEN
KH-KN	KAHVERENGİ	KENEVİR

Yıkamaya karşı renk haslığı testi yapılmış kumaşlarda yıkamaya karşı renk haslığı testine ait sonuçlar Tablo 2'de verilmiştir. Yıkamaya karşı renk haslığının lekeleme gri skalasındaki değerlendirmesinde en yüksek değerde olduğu görülmektedir. Yıkama sonrası yapılmış kumaşlarda renk değişiminin olduğu ve gri skala değerlendirilmesinde değerlerin kötü olduğu tespit edilmiştir

Tablo 2. Yıkama haslığı test sonuçları

Yıkama Haslığı Test Sonuçları							
Kumaş Kodu	**Renk Değişimi**	**Lekeleme**					
		Asetat	**Pamuk**	**Polyamid**	**Polyester**	**Akrilik**	**Yün**
Y-P	2	5	5	5	5	5	5
K-Y	1	4-5	5	5	5	4-5	5
S-KT	1	5	5	5	5	5	5
KH-KN	3	4-5	4-5	4-5	4-5	4-5	5

Kumaşlarda sürtünmeye karşı renk haslığı testine ait sonuçlar Tablo 2'de verilmiştir. Buna göre, yapılmış kumaşlarda atkı ve çözgü yönlerindeki yaş sürtme test sonucunun gri skalada değerlendirmesinde, değerlerin kuru sürtme atkı-çözgü yönlerinde kabul edilebilir değerler olduğu tespit edilmiştir. Yaş sürtme haslıklarında Y-P kodlu kumaş ve KH-KH kodlu kumaşın değerlerin kabul edilebilir değerlerin içinde olduğu ancak S-KT kabul edilebilir değer sınırındayken, K-Y kumaşların yaş sürtme haslıkları ise kabul edilebilir değerlerin altında kaldığı yapılan testlerde görülmüştür.

Tablo 3. Kumaşlara yapılan renk ölçümü

Kumaş Kodu	**L***	**a***	**b***	**C***	**h**	**X**	**Y**	**Z**	**x**	**y**
KH-KN	67,59	5,95	15,99	17,07	69,58	37,26	37,41	28,21	0,36	0,36
S-KT	67,75	1,53	11,57	11,67	82,47	36,13	37,63	31,44	0,34	0,36
Y-P	77,41	0,55	13,21	13,22	87,62	49,71	52,21	43,35	0,34	0,36
K-Y	72,39	14,25	22,62	26,73	57,79	46,83	44,24	29,32	0,39	0,37

Datacolor spectroflash 600 plus cihazında, CIELab D65 gün ışığı ve 100 lik gözlemci ile USAV 6,6 mm görüş alan plakaları kullanılarak renk ölçümü yapıldı. Bu ölçüm sonunda rengin renk düzlemi üzerindeki renk koordinatları (L*, a*, b*, C*, h, X, Y, Z, x, y) hesaplanarak sayısal değerleri belirlendi.

TASARIM VE UYGULAMA

Bu tez kapsamında geliştirilen koleksiyonun uygulama süreci, kalıp geliştirme, kumaş yerleşimi, kesim, dikim ve tamamlayıcı detayların işlenmesi gibi aşamaları kapsamaktadır. Her bir modelin üretiminde, hali hazırda var olan temel baz kalıplar referans alınmış, bu kalıplar tasarım çizimleri ve fonksiyonel ihtiyaçlar doğrultusunda yeniden biçimlendirilerek özgün model kalıplarına dönüştürülmüştür. Bu süreçte her bir ürün için geliştirilen kalıplar, boyama aşamasında elde edilen doğal elyaf içerikli kumaşlara minimum atık oluşturacak şekilde yerleştirilmiştir. Yerleştirme sırasında kumaşların en-boy yönündeki esneme oranları, dokuma yönü, kumaş yapısının stabilizesi ve kullanım anında karşılaşabileceği fiziksel etkiler göz önünde bulundurulmuştur. Kalıpların kumaşa uygulanması ve kesim işlemleri manuel olarak gerçekleştirilmiş, ardından dikim aşamasına geçilmiştir. Ürünlerin tamamı unisex ve tek beden prensibiyle tasarlanmış olup, kullanıcıya göre ayarlanabilir esnek bir yapı hedeflenmiştir. Dikim sürecinde kumaşların yapısal özellikleri dikkate alınarak hem makine dikişi hem de el dikişi tekniklerinden yararlanılmıştır. Bazı dikiş bölgelerinde tasarım manifestosuyla örtüşen biçimde bilinçli olarak “pis dikiş” uygulanmış, bazı parçalarda ise iç temizliğe önem verilerek “temiz dikiş” tercih edilmiştir. Gerekli görülen alanlarda overlok dikişiyle sağlamlık sağlanmış; her bir teknik karar, tasarımın ifade gücünü destekleyecek şekilde yapılandırılmıştır.



Görsel 11. Dikim aşaması

Dikim sürecinde kumaşların yapısal özellikleri dikkate alınarak hem makine dikişi hem de el dikişi tekniklerinden yararlanılmıştır. Bazı dikiş bölgelerinde tasarım manifestosuyla örtüşen biçimde bilinçli olarak “pis dikiş” uygulanmış, bazı parçalarda ise iç temizliğe önem verilerek “temiz dikiş” tercih edilmiştir. Gerekli görülen alanlarda overlok dikişiyle sağlamlık sağlanmış; her bir teknik karar, tasarımın ifade gücünü destekleyecek şekilde yapılandırılmıştır. Uygulama sürecinin son aşamasında, ürünlerin detaylandırılması ve karakteristik yapısının güçlendirilmesi amacıyla tamamlayıcı malzemeler kullanılmıştır. Doğal boyalarla renklendirilmiş yün iplikler, belirli bölümlerde el dikişleriyle dekoratif ya da işlevsel olarak

eklenmiş; aynı zamanda tahta düğmeler gibi doğal malzemelerle ürünlerin organik yapısı desteklenmiştir. Bu dokunuşlar, koleksiyonun el yapımı karakterini ön plana çıkarırken, sürdürülebilirlik ilkeleriyle de bütünlük kurmuştur (Görsel 12).



Görsel 12. Ürünlerin manifesto doğrultusunda hazırlanışı

Bu üretim süreci, yalnızca ürünlerin fiziksel olarak ortaya çıkarılmasını değil, aynı zamanda tasarımcının düşünsel yaklaşımını, teknik ve estetik tercihlerini, sürdürülebilirlik ilkeleriyle bütünleştirilmiş bir pratik düzleme taşımasını da temsil etmektedir.

Koleksiyonun Konsepti

Doğa ve beden arasındaki sınırları kaldıran, kumaşı bir arayüz değil bir deneyime dönüştüren bir koleksiyon: RAWBOUND. Bu koleksiyon, dokuların doğallığını koruyarak onları özgürce şekillendiren bir anlatı sunuyor. Her dikiş, doğanın saf halini ve insan elinin dönüştürücü gücünü içinde barındırıyor.

Geleneksel form algısını yıkan, bedensiz ve cinsiyetsiz tasarımlar, bedenin sınırlarını silerken bireysel özgürlüğü ön plana çıkarıyor. Tek bir kalıba sığmayan, her vücuda uyum sağlayan ve kişiye özel bir varoluş alanı sunan parçalar. RAWBOUND, giyimin sadece fiziksel bir katman değil, aynı zamanda bir kendini ifade biçimi olduğunu hatırlatıyor.



Görsel 13. Koleksiyon moodboardı

RAWBOUND, ham ve doğal dokuların kil ile boyanarak hayat bulduğu bir koleksiyon. Keten, pamuk, yün ve kenevir gibi sürdürülebilir materyaller, kilin organik pigmentleriyle birleşerek doğanın zengin renk paletini yansıtıyor. El işçiliğinin yavaş üretim anlayışıyla harmanlandığı bu süreç, her bir parçayı sadece bir giysi değil, aynı zamanda bir hikâye taşıyıcısına dönüştürüyor. Her kumaş, toprağın dokusunu ve insan emeğinin izlerini taşıyor. Endüstriyel hızın aksine, bilinçli ve dengeli üretimi savunan bu koleksiyon, hızlı tüketimin karşısında kalıcılığa, standardizasyonun karşısında ise bireyselliğe vurgu yapıyor. RAWBOUND, giysileri yalnızca bir nesne olarak değil, dönüşümün bir parçası olarak ele alıyor. Koleksiyonun her bir parçası, esnek ve modüler tasarım anlayışıyla şekilleniyor. Ayarlanabilir detaylar, birden fazla kullanım seçeneği ve bedene göre adapte olabilen formlar ile giysiler, kullanıcıya kendi bedenini ve tarzını keşfetme özgürlüğü sunuyor.



Görsel 14. Artistik ve teknik çizim paftası

• Crop Ceket: Yeşil kil ile boyanmış, çıkarılabilir kol detayları sayesinde iki farklı silüete bürünebilen çok yönlü bir parça.

• Fonksiyonel Yelek: Kırmızı kilin enerjisini taşıyan bu yelek, yan düğmelerle farklı vücut tiplerine uyum sağlayacak şekilde genişleyip daralabiliyor.

• Dinamik Şort: Siyah kilin zengin dokusuyla şekillenen keten şort, esnek bağcıklar ve kişiye özel ayarlanabilen detaylarla hareket özgürlüğü sağlıyor.

• Çok Yönlü Çanta: Doğal kenevir kumaşından üretilen bu çanta, işlevselliği sanatla birleştirerek farklı taşıma seçenekleri sunuyor.



Görsel 15. Ürünlerin bitmiş görselleri

Benzer Markalar & İlham Kaynakları

- Ziggy Chen – Doğal materyallerle zamansız ve bedensiz tasarımlar yaratıyor, minimal ama derin konseptlerle çalışıyor.
- Jamie Okuma – Yerel ve doğal boyama tekniklerini kullanarak kültürel mirası modern tasarımlarla buluşturuyor.
- Auralee – Doğal dokulara ve yumuşak tonlara odaklanan Japon markası, RAWBOUND'un renk skalası ve hissiyatı ile örtüşebilir.
- Seya – Seyahat ve doğanın izlerini taşıyan, yüksek kaliteli işçiliğiyle dikkat çeken bir marka.
- Toogood – Cinsiyetsiz, fonksiyonel, sanatsal formları ve el işçiliğini ön planda tutan tasarımlar sunuyor.

Moda & Tekstil Markaları

- Honest by Bruno Pieters – Şeffaf üretim süreciyle tamamen doğal kumaşlara odaklanan bir marka. Kumaş seçiminde etik ve sürdürülebilir kaynakları ön planda tutuyor.

- Story Mfg. – Doğal boyama teknikleri, organik kumaşlar ve geleneksel el işçiliği ile üretim yapan bir İngiliz markası. RAWBOUND'un kil boyama yöntemiyle uyumlu olabilir.
- E.L.V. Denim – Sıfır atık ve geri dönüştürülmüş denim kullanımıyla bilinen marka, RAWBOUND'un sürdürülebilirlik anlayışıyla kesişebilir.
- Veja – Organik pamuk ve doğal kauçuk gibi malzemeleri etik üretim süreçleriyle birleştiren bir ayakkabı markası. Kumaş bazlı aksesuarlar için işbirliği potansiyeli taşıyor.
- Kjinsen – Zamansız ve minimal tasarımlarla doğal kumaşları ön planda tutan, etik üretimi destekleyen bir marka.
- • Lug Von Siga – Sürdürülebilir moda odağında doğal malzemelerle üretim yapıyor. RAWBOUND'un hikâyesiyle ortak bir koleksiyon çıkarabilir.
- • Saye Artisan – Doğal keten ve pamuk kullanarak el dokuması tekstiller üreten bir marka. RAWBOUND'un doğal boyama teknikleriyle birleşebilir.
- • Direct Message – Minimal, bedensiz ve doğal kumaşlarla çalışan bir marka, ortak bir tasarım anlayışına sahip olabilir.

Sanat & El Sanatları

- İstanbul Bienali veya Salt Galata – Sanat ve moda kesişiminde, doğal pigmentler ve dokular üzerinden deneysel bir enstelasyon ya da performatif bir moda sunumu.
- İznik Vakfı – Geleneksel seramiklerde kullanılan doğal kil boyaları ile kumaş boyama arasında bir köprü kuran bir koleksiyon ya da workshop.

Doğa & Sürdürülebilirlik

- Ecording veya TEMA Vakfı – RAWBOUND'un bir parçası olarak doğaya geri dönüşümü teşvik eden bir proje: Koleksiyondan elde edilen gelirle ağaçlandırma çalışmaları yapılabilir ya da kıyafetlere gömülebilir tohumlu etiketler eklenebilir.
- EkoKilit / Doğal Boyamacılar ile İş birliği – Türkiye'de doğal boya teknikleriyle çalışan zanaatkârlarla iş birliği yaparak koleksiyona bölgesel bir kimlik kazandırmak.

Sosyal Etki

- Kadın Kooperatifleri (S.S. Anatolian Craft, Mavi Kalem Derneği) – Koleksiyonun belirli parçalarının yerel kadın üreticilerle birlikte el işçiliğiyle üretilmesi.
- Mor Çatı veya LOOM Türkiye – Kadın hakları ve toplumsal cinsiyet eşitliği üzerine farkındalık yaratacak bir moda projesi.

RAWBOUND'un özü, sadece estetik ve tasarımda değil, üretim ve topluma katkı noktasında da güçlü bir bağ kurabilir. Hem sanatsal hem de toplumsal bir duruş sergileyen bu marka, lokal ve küresel iş birlikleri ile daha geniş bir anlatıya dönüşebilir.

SONUÇ VE ÖNERİLER

Bu çalışma kapsamında, doğal kil pigmentleri kullanılarak pamuk, keten, kenevir ve yün gibi doğal elyaf yapısına sahip kumaşlara doğal boyama işlemleri uygulanmıştır. Boyama süreçlerinde farklı kil türleri (yeşil, kırmızı, siyah) kullanılmış, ayrıca bu killerin karışımıyla kahverengi tonlar elde edilmiştir. Boyama öncesi kumaşlara uygulanan mordanlama işlemleri ile boyanın lif yüzeyine tutunması desteklenmiş, boyama sonrası fikseleme adımıyla renk kalıcılığı sağlanmaya çalışılmıştır. Deneme ve uygulama aşamaları karşılaştırıldığında, kullanılan kilin süzülüp süzülmemesi, mordan oranlarının farklılaştırılması gibi teknik detayların renk yoğunluğu ve kumaş yüzeyindeki dağılım üzerinde belirleyici olduğu tespit edilmiştir. Sürdürülebilir bir boyama prosesi olan bu deneysel çalışmada çevreye zarar vermeyen doğal boyama tekniği olarak tercih edilmektedir. Ancak burada boyamanın zorluğu ve tekrarlanabilirliği bu yöntemin dezavantajı olarak bilinmektedir.

Kil boyamanın kumaşlarda yıkama haslıklarının lekeleme yönünde yüksek olduğu buna karşın ise solma değerlerinin düşük olduğu tespit edilmiştir. Burada yıkama işlemleri sonunda boyarmaddenin kumaştan uzaklaşması sonucu leklemelerin iyi olduğu ancak kumaşta boyarmaddenin uzaklaştığı bu yüzden yaş haslıklarının düşük olduğu söylenebilir. Bunun kumaşa bağlanan boyarmaddenin yeterince bağlanamadığını göstermektedir. Bu sebepten dolayı kumaşların yaş işlem veya sulu ortamlarda meydana gelecek dış etkenlerden etkileneceği ve materyallerin kullanım alanını doğru bir şekilde seçilmesi gerekmektedir.

Kumaş açısından selülozik esaslı lifler pamuk ve kenevir, yün ve ketene göre haslık açısından daha kullanılabilir olduğu yapılan haslık testlerinden görülmektedir.

Elde edilen bulgular, çevresel açıdan sürdürülebilir bir alternatif sunduğunu ortaya koymaktadır. Kumaşların kullanım amacı gözetildiğinde kullanıldıkça yıpranan bir rengin moda ve tasarım açısında kullanılması daha doğru olacağı görülmektedir. Çalışma kapsamında elde edilen boyalı kumaşlar hem tasarımsal ürünler üretmekte kullanılmış hem de çeşitli fiziksel testlerle değerlendirilmiştir. Bu yönüyle çalışma, doğal boyamacılıkta kil pigmentlerinin etkinliğini ortaya koyan öncü bir örnek sunmaktadır.

Kil boyama ile elde edilen renklerin zamanla değişim göstermesi, klasik anlamda renk stabilizesinin dışına çıksa da, bu özellik kumaşın yaşamsallığını ve geçirdiği dönüşümü yansıtarak ürünün uzun ömürlü kullanımına dair farklı bir yorum sunar. Bu değişim süreci, kumaşa bireysel bir hikâye kazandırır ve tasarımı statik değil, zamanla evrilen bir obje haline getirir. Bu yönüyle kil boyama, estetik bir tercih ve tasarımsal bir anlatı unsuru olarak değerlendirilebilir.Bu bağlamda, kil boyama yöntemi özellikle kişiye özel tasarımlar, sınırlı sayıda üretilen sanatsal koleksiyonlar ve konsept moda ürünleri için sürdürülebilir, doğaya duyarlı ve yaratıcı bir alternatif oluşturmaktadır. Bu tür tasarımlarda, rengin zamanla değişimi bir kusur değil, tasarımın yaşayan bir parçası olarak kabul edilmekte; kullanıcı ile ürün arasında duygusal bir bağ kurulmasına olanak sağlamaktadır.

Ticari açıdan bakıldığında ise bu yöntemin potansiyeli, niş pazarlar, hikâye temelli moda pratikleri ve zanaat temelli üretim modelleri ile desteklenebilir. Sürdürülebilirlik ilkelerini benimseyen butik markalar, yerel üretimi esas alan tasarımcı atölyeleri veya kültürel bağlamdan beslenen projelerde, kil boyama farklılaştırıcı ve değer odaklı bir uygulama olarak öne çıkabilir. Ayrıca, yerel ve doğal malzemelerle gerçekleştirilebilmesi sayesinde ekolojik ve ekonomik sürdürülebilirlik açısından da avantajlıdır.

Doğal kil boyama yöntemi hem çevre dostu yapısı hem de düşük atık üretimi ile sürdürülebilir tekstil arayışları açısından önemli bir potansiyel taşımaktadır. Ancak ülkemizde bu yönteme dair akademik ve sektörel çalışmalar oldukça sınırlıdır. Türkiye'nin zengin kil yataklarına sahip

olması, bu doğal malzemenin tekstil boyamacılığında kullanımı için büyük bir avantaj sunmaktadır. Bu nedenle, kil temelli doğal boyaların yerli üretimle desteklenmesi, araştırmalarla geliştirilmesi ve uygulama tekniklerinin yaygınlaştırılması hem çevre sağlığına katkı sağlayacak hem de yerli üretim politikalarına hizmet edecektir.

Günümüz tekstil sektöründe hâkim olan sentetik boyar maddeler hem insan sağlığı hem de çevre açısından ciddi riskler barındırmaktadır. Özellikle üretim ve yıkama süreçlerinde ortaya çıkan kimyasal atıklar, su kaynakları ve ekosistemler üzerinde kalıcı etkiler yaratmaktadır. Bu bağlamda kil gibi doğal kaynaklardan elde edilen boyalar, atıksız, toksik olmayan ve doğayla uyumlu bir alternatif sunmaktadır. Bu yöntemin, geleneksel tekstil teknikleriyle yeniden ilişkilendirilerek çağdaş üretim sistemlerine entegre edilmesi mümkündür.

Ayrıca bu yöntem, düşük maliyetli oluşu ve kolay erişilebilen hammaddelere dayanması bakımından küçük ölçekli üreticiler, yerel zanaatkârlar ve sürdürülebilir tasarım pratikleri yürüten girişimler için uygulanabilir bir model sunmaktadır. Gelecekte yapılacak çalışmalarda, farklı kil türlerinin içerdiği metal oksitlerin renk üzerindeki etkileri detaylı biçimde incelenmeli, ayrıca bu pigmentlerin farklı tekstil elyafları üzerindeki renk dayanımı testleri geniş kapsamda değerlendirilmelidir.

Bunun yanı sıra, doğal boyamacılık tekniklerinin tekstil eğitimi müfredatlarına entegre edilmesi, tasarımcıların alternatif malzeme bilgisi geliştirmesi açısından önemlidir. Aynı zamanda bu yöntemin, biyobozunur ve vegan üretim süreçleri arayan yeni nesil tüketiciler açısından da değerli bir yaklaşım olabileceği düşünülmektedir.

Sonuç olarak, kil boyama yöntemi endüstriyel üretim kalıplarının dışında kalan; ancak çağdaş moda dünyasında giderek önem kazanan anlam odaklı, çevresel duyarlılığı yüksek ve estetik çeşitliliği destekleyen tasarım anlayışlarına güçlü bir katkı sağlayabilir. Gelecek araştırmalarla bu yöntemin farklı doğal hammaddelerle veya post işlem teknikleriyle geliştirilmesi, hem estetik hem de performans açısından daha geniş bir uygulama alanı açabilir.

Teşekkürler ve Bilgi Notu

Bu çalışmanın yürütülmesi sürecinde, özellikle boyama prosesleri ve test uygulamaları konusundaki bilgi ve tecrübeleriyle değerli katkılar sunan Marmara Üniversitesi öğretim üyesi Doç. Dr. Bekir Cenkkut Gültekin'e ve destekleriyle çalışmama katkı sağlayan Arş. Gör. Onur Atak'a teşekkürlerimi sunarım. Ayrıca her aşamasında akademik rehberliği, yönlendirmeleri ve sürekli desteği ile katkıda bulunan danışmanım Haliç Üniversitesi Dr. Öğr. Üyesi Vedat Özyazgan'a içten şükranlarımı arz ederim.

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OCCUPATIONAL SAFETY IN ORAL AND DENTAL HEALTH HOSPITALS

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ABSTRACT

The duties, authorities, responsibilities, rights and obligations of employers and employees to ensure occupational health and safety in Oral and Dental Hospital and to improve current health and safety conditions are regulated by the Occupational Health and Safety Law Numbered. 6331, which was adopted on the June 6th, 2012. According to the Workplace Hazard Classes Communiqué on Occupational Health and Safety, which was adopted on the December 26th, /2012, the field of activity of Oral and Dental Health Hospitals is in the very hazardous class and carries all risks related to physical, chemical, biological, ergonomic, psychosocial and the services provided. The aims of occupational safety is all the activities that need to be carried out for the employees and students in the hospital to maintain their normal health, and the aim is to protect the employees from occupational accidents and occupational diseases. The risk assessment carried out within this scope includes the studies that need to be carried out to determine the existing or external hazards and to eliminate the factors that cause these hazards to turn into risks. These studies are to determine the risks that may negatively affect the patient, patient relatives, visitors, employees and the environment, including the interns and those receiving vocational training in the institution. Risks are combated at their source, if this is not possible, the risk level is reduced to an acceptable level in the environment or target. Risk assessment studies should be carried out in coordination with the relevant boards such as the quality management unit, occupational health and safety units, and the patient safety committee. In this study, the studies that need to be carried out to ensure occupational safety in Oral and Dental Health Hospitals are discussed and solution suggestions are presented.

Keywords: Oral and Dental Health Hospital, occupational safety, risk, danger.

AĞIZ VE DİŞ SAĞLIĞI HASTANELERİNDE İŞ GÜVENLİĞİ

ÖZET

Ağız ve Diş Sağlığı Hastanelerinde iş güvenliğinin sağlanması, mevcut sağlık ve güvenlik koşullarının iyileştirilmesi için işveren ve çalışanların görev, yetki, sorumluluk, hak ve yükümlülükleri 20/06/2012 tarihinde kabul edilen 6331 Sayılı İş Sağlığı ve Güvenliği Kanunu ile düzenlenmiştir. 26/12/2012 tarihin yürürlüğe giren İş Sağlığı ve Güvenliğine İlişkin İşyeri Tehlike Sınıfları Tebliğine göre Ağız ve Diş Sağlığı Hastaneleri faaliyet alanı çok tehlikeli sınıfta yer almakta ve fiziksel, kimyasal, biyolojik, ergonomik, psikososyal ve sunulan hizmetlere ilişkin tüm riskleri taşımaktadır. İş güvenliğinin amacı hastanede çalışanların, öğrencilerin, normal sağlıklı hallerini sürdürmeleri için yürütülmesi gereken faaliyetlerin tümü ve hedefi çalışanları, iş kazası ve meslek hastalıklarından korumaktır. Bu kapsamda yapılan risk değerlendirmesi var olan ya da dışarıdan gelebilecek tehlikelerin belirlenmesi, bu tehlikelerin riske dönüşmesine yol açan faktörlerin ortadan kaldırılması için yapılması gereken çalışmaları kapsar. Bu çalışmalar stajyer ve kurumda mesleki eğitim alanlar dahil olmak üzere hasta, hasta yakını, ziyaretçi, çalışan ve çevreyi olumsuz etkileyebilecek risklerin belirlenmesidir. Risklerle kaynağında mücadele edilir, bu mümkün değilse risk düzeyi ortam veya hedefte kabul edilebilir seviyeye indirilir. Risk değerlendirme çalışmaları kalite yönetimi birimi, iş sağlığı ve güvenliği ile ilgili birimler, hasta güvenliği komitesi gibi ilgili kurullar ile koordineli şekilde yürütülmelidir. Bu çalışmada Ağız ve Diş Sağlığı Hastanelerinde iş güvenliğinin sağlanması için yapılması gereken çalışmalar ele alınmış ve çözüm önerileri sunulmuştur.

Anahtar Kelimeler: Ağız ve Diş Sağlığı Hastanesi, iş güvenliği, risk, tehlike.

1- GİRİŞ

Dünya Sağlık Örgütü (WHO) sağlığı kişinin bedenen, ruhen ve sosyal yönden tam iyilik hali olarak tanımlamaktadır. Sağlık çalışanlarının iş güvenli ve sağlığının korunması için, çalışma ortamında fiziksel, kimyasal, biyolojik, psikolojik, ergonomik tehlike tespit edilmesi ve risk değerlendirmesinin yapılması gerekir. İş güvenliği, Fakülte, Klinik ve hastanede çalışanların, öğrencilerin, hastaların normal sağlıklı hallerini sürdürmeleri için yürütülmesi gereken faaliyetlerin tümüdür. İş Güvenliğinin temel amacı iş kazalarının önüne geçmek ve çalışanları meslek hastalıklarından korumaktır. Ülkemizde çalışan güvenliğinin sağlanması için 2015 yılında Sağlık Bakanlığı tarafından hazırlanan "Sağlıkta Kalitenin Geliştirilmesi ve Değerlendirilmesine Dair Yönetmeliği" yürürlüğe girmiştir.

2- İŞ SAĞLIĞI VE GÜVENLİĞİ UYGULAMASI

İşveren ya da İşveren Vekili 6331 sayılı İş Sağlığı ve Güvenliği Kanunu ve İş Sağlığı ve Güvenliği Risk Değerlendirmesi Yönetmeliği uyarınca diş klinik ve hastanelerinde tehlike ve risk analizi yapmak veya yaptırmakla yükümlüdür. Risk değerlendirmesi; diş klinik ve hastanede var olan ya da dışarıdan gelebilecek tehlikelerin belirlenmesi, bu tehlikelerin riske dönüşmesine yol açan faktörlerin ortadan kaldırılması için yapılması gereken çalışmaları kapsar. 26/12/2012 tarihli İş Sağlığı ve Güvenliğine İlişkin İşyeri Tehlike Sınıfları Tebliğine göre Diş Klinikler ile Ağız ve Diş Sağlığı Hastanesi faaliyet alanı çok tehlikeli sınıfta yer almaktadır.

Ağız ve Diş Sağlığı Hastanelerinde tehlikelerin kaynakları acil durum, asansör, atıklar, biyolojik etkenler, yangın, tanklar, basınçlı tüpler, cam yüzeyler, eğitim ve bilgilendirme, ekranlı araçlarla çalışma, elektrik, elle taşıma, ergonomi ve monoton çalışma, depolar, ışıma-radyasyon, iklimlendirme-havalandırma, haşereler ve kemirgenler, ilkyardım malzemeleri, istif ve sabitleme, jeneratör, kaygan zemin, kesici delici aletler, kimyasal maddeler, kombi/kazan dairesi, psikososyal etkenler, sterilizasyon, su depoları, tavana sabitlenen malzemeler, hijyeni koşulları, yüksekte çalışma ve zemin sorunları şeklinde sıralanabilir (Güler, 2004; Çetik ve Oğulata, 2023). Bahsi geçen tüm tehkile kaynaklarına bağlı risklerin değerlendirmesi fiziksel, kimyasal, biyolojik, ergonomik, psikososyal ve sunulan hizmetlere ilişkin tüm riskleri içermektedir. Risk değerlendirmesi Sağlık Kalite Sistemi kapsamında hasta, hasta yakını, ziyaretçi ve çalışanlara yönelik riskler Tıbbi hizmetler, Yönetsel hizmetler, Tesis güvenliği, çevre güvenliği, İş sağlığı ve güvenliği.

Malzemelerin yerli yerinde olmaması, temizlenmemesi ve sterilize edilmemesi, işyerinin temizliği ve hijyen şartlarının uygun olmaması, çalışma ortamının dar olması, çöpler ve atıklar (atık kutularının ağızlarının açık olması ve ünitlere yakın olması, her boşaltmadan sonra dezenfekte edilmemesi), toz oluşumu, sterilizasyon amaçlı kullanılan araç ve malzemelerin kullanım talimatlarının bulunmaması iş yeri düzeni ve hijyen sorunlarını oluşturmaktadır. Sağlık birimlerinde iş yeri düzeni ve hijyen sorunları iş güvenliği riski oluşturmaktadır. Makinelerin hareketli parçaları, basınçlı kaplar, lazer ile çalışan cihazlar, el aletleri ya da teknik aparatlar, röntgen cihazları, bisturi yaralanması, enjektör batması sonucu sıklıkla karşılaşılan iş kazalarına neden olmaktadır. İş Güvenliğinde Psikososyal Risk Etmenleri, işin mahiyeti, iş yükü ve temposu, iş programı, ilişkiler ve kariyere göre değişiklik gösterir. Yoğun çalışmaların yapıldığı alanlara, kliniklere ve laboratuvarlara, ziyaretçilerin veya hastaların girişleri psiko-sosyal risk etmenlerini oluşturur (Gül, 2009; Özer vd., 2005). Ergonomik bir oturma pozisyonu, vücut yapısına uygun ve uzun süreli oturmanın yol açabileceği sağlık sorunlarını en aza indirgeyen bir duruştur (https://www.csgb.gov.tr/media/4587/rehber06.pdf). Bu pozisyon, omurganın doğal eğrisini destekler, eklem ve kas gerginliğini azaltır ve kan dolaşımını iyileştirir. Çalışma ortamında uygun olmayan duruş pozisyonlarda çalışma, Çalışmalarda,

yapılan işe uygun olmayan masa, sandalye veya destek ekipmanları iş sağlığı güvenliği açısından risk oluşturur.

Kullanılmış iğne, bisturi, katater iğnesi gibi kirli, kesici, delici aletler ele battığında ya da başkasının eline batması halinde çok ciddi hastalıklara sebep olabilir. Kesici-delici ve kirli aletler kullanılırken yaralanmaya karşı dikkatli olunmalıdır. Hastada kullanılan kanlı enjektörleri iğneleri dışarıda kalmayacak şekilde, kesinlikle kapaklarını kapatmadan sarı tıbbi atık kovası içine atılmalı, asla çöp kovasına atılmamalıdır.

Afetler (Deprem, Sel vb.), yangın, trafik kazaları, elektrik çarpması, kimyasal dökülme, iş kazaları, acil müdahale ve ilk yardım gerektiren durumlar, herhangi bir kazaya veya yaralanmaya sebep olmamış, ancak buna yol açmak üzere olan durumlar (elektrik kaçağı vb.) acil durumdur. Acil durum çalışma ortamında normal iş akışını bozan veya durmasına sebep olan olaylardır. Olayların oluşturabileceği kriz halini önceden belirlenmesi ile hızlı bir şekilde müdahale edilerek iş sürekliliğinin devamı sağlanabilir (Özmen vd. 2015). Acil Durum planları kapsamında Yangınla Mücadele (Söndürme), Arama ve Kurtarma, Tahliye Ekibi, İlk Yardım Ekipleri oluşturulmaktadır. Hastanede olağanüstü durumlarda; Fiziksel veya sözel taciz, şiddet, saldırı vb. durumlarda Beyaz Kod (1111), Kalp ve solunum durması veya yaşamı tehdit eden durumlarda Mavi kod (2222)**,** Bebek ve çocuk güvenliğinde Pembe Kod (3333), Yangın, doğal afet ve kaza durumlarında Kırmızı Kod (4444) kullanılır.

Sağlık çalışanlarının sıklıkla tüberküloz, menengokoksik menenjit, gastrointestinal sistem enfeksiyonları, lejyoner hastalığı, difteri, boğmaca, hepatit-b, kızamık, kızamıkçık, kabakulak, suçiçeği veya varisella zoster, herpes enfeksiyonları, sitomegalovirüs enfeksiyonları, edinsel bağışıklık yetersizliği sendromu ve histoplazmosis gibi sağlık sorunları ile karşılaşmaktadırlar (Görgüner, 2002). Ameliyathanede, enjektör kullanımında ve temizlik aşamalarında bu tür riskle maruz kalınmaktadır (Yürügen ve Durna, 1992; Merih vd., 2009; Anık, 2004). Sağlık çalışanlarının kişisel koruyucu donanım (KKD) kullanması zorunludur. KKD'lerin temini ve kullanımının sağlanması işverenin yükümlülüğündedir (Demirbilek ve Çakır, 2008). Aynı zamanda ortamda koruyucu nitelikte saçılma kiti sağlık tesislerinde bulundurulması gerektedir.

3- SONUÇLAR

Ağız ve diş sağlığı hastanelerinde gözlemlenen başlıca tehlikeler, çalışanlar, hastalar ve ziyaretçiler üzerinde doğrudan etkili olabilecek acil durumlar ile mekanik ve elektrikli iş ekipmanlarının yönetimi kapsamında ortaya çıkmaktadır. Bu tür sağlık tesislerinde, özellikle acil bir durumda, hasta, engelli, yaşlı ve gebe bireyler dâhil olmak üzere tüm kişilerin hızlı ve güvenli bir şekilde tahliye edilmesi büyük önem taşımaktadır. Bu nedenle bina tasarımı, acil tahliyeyi kolaylaştıracak şekilde planlanmalı ve tahliye yolları açık, erişilebilir ve işaretlenmiş olmalıdır.

Hastanenin fiziksel altyapısı, patlama, yangın ve elektrik kaçağı gibi risklere karşı düzenli olarak denetlenmeli; bu risklerin oluşmasına neden olabilecek tüm unsurlar kontrol altında tutulmalıdır. Özellikle kazanlar, basınçlı kaplar, gaz tüpleri, kompresör sistemleri, asansörler ve diğer elektrikli iş ekipmanları, düzenli bakım ve periyodik kontrollerle güvenli bir şekilde yönetilmelidir.

Bununla birlikte, sağlık çalışanlarının hastalarla yakın temas içinde çalışması, biyolojik riskleri de gündeme getirmektedir. Enfeksiyon kontrol önlemleri, kişisel koruyucu donanım kullanımı ve hijyen protokolleri, bu tür risklerin önlenmesi açısından hayati öneme sahiptir. Özellikle ağız yoluyla bulaşabilecek enfeksiyonlara karşı korunma, bu hastanelerde iş güvenliği kapsamında öncelikli olarak ele alınmalıdır.

İş sağlığı ve güvenliği uygulamalarının temel ilkesi, tehlikelerin kaynağında ortadan kaldırılmasıdır. Bu amaçla, yasal yükümlülüklerin eksiksiz şekilde yerine getirilmesi ve etkili bir işletme yönetiminin sağlanması, ağız ve diş sağlığı hastanelerinde iş güvenliğini sağlamanın temel koşulları arasında yer almaktadır.

Sonuç olarak, yüksek risk içeren bu tür sağlık tesislerinde, öncelikli hedef; risklerin tespit edilmesi, önleyici tedbirlerin alınması ve tüm çalışanların iş sağlığı ve güvenliği kültürüyle donatılması olmalıdır.

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DETERMINATION OF NURSING STUDENTS' TECHNOSTRESS LEVELS IN A TECHNOLOGY-SUPPORTED LEARNING ENVIRONMENT

HEMŞİRELİK ÖĞRENCİLERİNİN TEKNOLOJİ DESTEKLİ ÖĞRENME ORTAMINDA TEKNOSTRES DÜZEYLERİNİN BELİRLENMESİ

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ÖZET

Giriş: Dijital teknoloji çağının getirdiği dönüşümler doğrultusunda, üniversiteler eğitim-öğretim süreçlerinde sanal öğrenme ortamları, mobil cihazlar, akıllı ders yönetim sistemleri ve yapay zekâ destekli uygulamalar gibi çeşitli teknolojik araçları yaygın biçimde kullanmaya başlamıştır. Ancak bu teknolojilerin eğitim bağlamında yoğun biçimde entegrasyonu, özellikle teknolojiyi daha çok eğlence ya da bireysel ilgi amaçlı kullanan genç bireylerde teknostrese neden olabilmektedir.

Amaç: Bu çalışmada teknoloji destekli öğrenme ortamında hemşirelik öğrencilerinin teknostres düzeylerinin belirlenmesi amaçlanmaktadır.

Yöntem: Çalışma tanımlayıcı tipte yapılmıştır. Çalışmanın örneklemini 430 hemşirelik bölümü öğrencisi oluşturmuştur. Verilerin toplanmasında 'Kişisel Bilgi Formu' ve 'Teknostres Ölçeği' kullanılmıştır.

Bulgular: Öğrencilerin, Teknostres Ölçeği toplam puan ortalamaları 31.0±10.70'tür. Öğrencilerin cinsiyetine, sınıf düzeyine, teknoloji kullanımı konusunda eğitim alıp almama durumuna ve günlük internet kullanım süresine göre teknostres düzeyleri arasında anlamlı bir fark bulunmamaktadır ($p>0,05$).

Sonuç: Araştırma sonucunda öğrencilerin orta düzeyde teknostres yaşadıkları belirlenmiştir. Bu bağlamda, üniversitelerin teknoloji entegrasyon sürecinde öğrencilerin olası stres düzeylerini göz önünde bulundurması ve dijital okuryazarlıklarını geliştirmeye yönelik destekleyici uygulamalarla bireysel farklılıkları dikkate alan rehberlik hizmetleri sunması önerilebilir.

Anahtar kelimeler: Teknostres, Hemşirelik öğrencileri, Teknoloji destekli eğitim

GİRİŞ

Bilgi ve iletişim teknolojilerinin kullanımı son yıllarda artış göstermiştir. Özellikle Covid-19 salgını sanal eğitim ve öğretim araçlarının kullanılmasını hızlandırmıştır (Montes de Oca López et al., 2021). Bilgi ve iletişim teknolojilerinin eğitim sistemine entegrasyonu, öğrenmenin doğasını, yöntemlerini ve süreçlerini dönüştürmüş; ayrıca mevcut eğitim modellerini geliştirerek teknoloji destekli yeni öğretim ve öğrenme yaklaşımlarının ortaya çıkmasını sağlamıştır (Abdullah et al.,2016; Talebian et al.,2014; Zokirovna,2020). Teknoloji destekli öğrenme, dijital teknolojiler yoluyla öğrenme süreçlerinin desteklenmesi, kolaylaştırılması ve zenginleştirilmesi şeklinde tanımlanmaktadır. (Dunn and Kennedy,2019). Bu öğrenme yaklaşımı, bireysel ya da işbirlikçi öğrenme ortamlarında bilgiye erişimi kolaylaştırmak, etkileşimi artırmak ve öğrenme deneyimlerini kişiselleştirmek amacıyla bilgisayarlar, internet tabanlı platformlar ve dijital uygulamalar gibi çeşitli teknolojik araçların kullanımını kapsamaktadır (Jing et al.,2024).

Yükseköğretim kurumlarında bilgi ve iletişim teknolojileri, akademik faaliyetlerin yönetimini kolaylaştırmakta, karar alma süreçlerinde şeffaflığı teşvik etmekte ve veri işleme süreçlerini hızlandırmaktadır. Ayrıca, teknolojinin sınıf ortamlarına entegrasyonu, öğrenme ve öğretme süreçlerinin kalitesini artırmada önemli bir etkiye sahiptir (Mirzajani et al., 2016). Öğrenciler arasında bilgi ve iletişim teknolojilerinin yoğun kullanılmasının olumlu etkilerinin yanında teknostres gibi olumsuz etkiler de dikkate alınmalıdır (Velasquez ve Paz, 2020). "Teknostres" kavramı ilk kez Brod (1984) tarafından ortaya atılmıştır. Brod'a göre teknostres, bireylerin yeni bilgisayar teknolojilerine uyum sağlamakta zorlanmaları sonucunda ortaya çıkan bir tür uyum bozukluğudur (Brod,1984). Son çalışmalarda ise teknostres, bireylerin dijital teknolojilere (internet, cep telefonları, dizüstü bilgisayarlar, uzaktan çalışma ve sanal eğitim gibi) sürekli maruz kalmaları ve bu teknolojileri yoğun şekilde kullanmaları sonucunda ortaya çıkan bilişsel ve psikolojik stres durumu" olarak tanımlanmıştır (Cari Calcina, 2021; Tarafdar et al., 2017). Teknostres, bireylerde hem fiziksel hem de psikolojik çeşitli sağlık sorunlarına yol açabilmektedir. Fiziksel açıdan değerlendirildiğinde, kardiyovasküler rahatsızlıklar, gastrointestinal problemler, uyku bozuklukları ve kas ağrıları gibi semptomlar ortaya çıkabilmektedir. Psikolojik boyutta ise motivasyon kaybı, artan sinirlilik düzeyi ve depresif ruh hali gibi olumsuz etkiler gözlemlenebilmektedir (Chiappetta, 2017). Ponce Pardo ve arkadaşlarının (2023) Peru'daki üniversite öğrencileri ile yaptığı çalışmada %49,4'ünde orta düzeyde teknostres ortaya çıkmıştır. Ayrıca bu durumun katılımcıların akademik üretkenlikleri ile ruh sağlıkları üzerinde olumsuz etkiler yarattığı belirlenmiştir (Ponce Pardo et al.,2023) Teknostres, üniversite öğrencilerinde tükenmişlik, öğrenmeye katılımda isteksizlik, verimlilikte azalma ve teknoloji destekli öğrenmeden ayrılma isteğine neden olabilmektedir (Upadhyaya ve Vrinda, 2021; Zhao et al.,2022)

Yükseköğretimde teknoloji destekli öğrenmenin giderek yaygınlaşması, öğrencilerin teknostres düzeylerinin ve bu düzeyleri etkileyebilecek çeşitli faktörlerin belirlenmesini önemli ve gerekli kılmaktadır. Uygulamalı bir eğitim sürecinden geçen hemşirelik öğrencileri hem teorik derslerinde hem de klinik uygulamalarında bilgi ve iletişim teknolojilerine yoğun biçimde maruz kalmaktadır. Literatürde, hemşirelik eğitiminde teknoloji destekli öğrenmenin öğrenci memnuniyeti ve akademik başarısı üzerindeki etkilerine yönelik çeşitli çalışmalar yer almaktadır. Bununla birlikte, teknoloji destekli öğrenme ortamlarının öğrencilerde oluşturabileceği olumsuz etkilerden biri olan teknostresin düzeyinin belirlenmesi ve etkileyebilecek faktörlerin anlaşılması önem arz etmektedir. Bu çalışmada, teknoloji destekli öğrenme ortamlarında hemşirelik öğrencilerinin teknostres düzeylerinin belirlenmesi amaçlanmaktadır. Elde edilecek bulguların teknostres konusunda farkındalık oluşturacağı,

hemşirelik öğrencilerinin eğitim süreçlerinde bu kavramın daha iyi anlaşılmasına katkı sağlayacağı ve ileride yapılacak araştırmalar için de yol gösterici olacağı düşünülmektedir.

Araştırma Soruları

1- Hemşirelik öğrencilerinin teknostres düzeyleri nedir?

2- Hemşirelik öğrencilerinin teknostres düzeyi bazı tanımlayıcı özelliklere göre değişiklik gösterir mi?

MATERYAL VE YÖNTEM

Araştırmanın Tipi

Bu araştırma, tanımlayıcı tipte yapılmıştır.

Araştırmanın Evren ve Örneklemi

Araştırmanın evrenini bir üniversitenin Sağlık Bilimleri Fakültesi 2024-2025 eğitim-öğretim yılı bahar yarıyılında öğrenim gören 600 hemşirelik bölümü öğrencisi oluşturmuştur. Araştırmada evrene ulaşabilme imkânı olduğundan örneklem seçimine gidilmemiş çalışmaya katılmayı kabul eden 430 (%71.6) öğrenci ile çalışma tamamlanmıştır.

Verilerin Toplanması

Veriler Nisan-Mayıs 2025 tarihleri arasında "Öğrenci Bilgi Formu" ve "Teknostres Ölçeği" kullanılarak çevrim içi anket yöntemi ile toplanmıştır. Uygulama öncesi öğrencilerin ders programından uygun oldukları gün ve saatler belirlenmiştir. Belirlenen gün ve saatlerde öğrencilere çalışmaya ilişkin bilgilendirme yapılmış daha sonra çalışmaya katılmaya gönüllü olan öğrenciler ile veri toplama formlarına ilişkin link paylaşılmıştır. Veri toplama formlarının doldurulması yaklaşık 10 dakikada tamamlanmıştır.

Öğrenci Bilgi Formu; Literatür taranarak (Dunn and Kennedy,2019; Seçer, 2024; Wang et al., 2021) araştırmacılar tarafından oluşturulmuştur. Öğrencilerin cinsiyet, yaş, sınıf düzeyi, teknoloji kullanımı ile ilgili herhangi bir eğitim alma durumu ve günlük internet kullanım süresinin sorgulandığı 5 sorudan oluşmaktadır.

Teknostres Ölçeği: Ölçek, Wang ve ark. (2020)'ları tarafından geliştirilmiştir (Wang et al.,2020). Türkçe geçerlilik ve güvenilirlik çalışması Baş ve arkadaşları tarafından 2021 yılında yapılmıştır (Baş vd.,2021). Öğrencilerin teknostres düzeylerinin değerlendirilmesinde kullanılmaktadır. On üç sorudan oluşan ölçek, beşli likert tipte olup bu ölçekten minimum 13 puan, maksimum 65 puan alınabilmektedir. Puan yükseldikçe teknostres düzeyi artmaktadır. Ölçeğin Türkçe uyarlama çalışmasında Cronbach alfa değeri 0.91 (Baş vd.,2021), bu çalışmada ise 0.95 olarak hesaplanmıştır.

Verilerin Analizi

Çalışmadan elde edilen verilerin analizi bir istatistik programı olan Jamovi 2.6.13 kullanılarak gerçekleştirilmiştir. Hemşirelik öğrencilerinin tanımlayıcı özelliklerine ilişkin verilerin değerlendirilmesinde sayı ve yüzde, teknostres düzeylerini belirlemek için ortalama ve standart sapma değerleri kullanılmıştır. Öğrencilerin teknostres düzeyinin bazı tanımlayıcı özelliklere göre farklılık gösterip göstermediğini belirlemek için t-testi ve Tek yönlü varyans analizi kullanılmıştır. Anlamlılık düzeyi $p<0.05$ olarak kabul edilmiştir.

Araştırmanın Etik Yönü

Araştırmanın yürütülebilmesi için etik kurul (28.03.2025 tarihli ve 2025/03 nolu toplantı) onayı ve araştırmanın yürütüldüğü kurumdan Kurum izni (11.04.2025 tarihli ve E-57323016-010.99-

426124 sayılı) alınmıştır. Araştırmada kullanılan ölçek için kullanım izni alınmıştır. Çalışma tamamen gönüllülük esasına dayalı olarak gerçekleştirilmiş ve katılımcılardan Bilgilendirilmiş Olur Formu alınmıştır.

BULGULAR VE TARTIŞMA

Hemşirelik öğrencilerin tanımlayıcı özellikleri Tablo 1'de yer almaktadır. Buna göre öğrencilerin yaş ortalaması 21.23'tür.Öğrencilerin %64.2'ünün kadın, %40'ının 2.sınıf olduğu ve %75.8'inin teknoloji kullanımıyla ilgili eğitim almadığı, %45.3'ünün ise 4 saat ve üzeri günlük internet kullanımı olduğunu belirlenmiştir (Tablo 1).

Tablo 1. Hemşirelik Öğrencilerinin Tanımlayıcı Özellikleri (n=430)

Özellik	n	%
Cinsiyet		
Kadın	276	64.2
Erkek	154	35.8
Sınıf		
1. Sınıf	100	23.3
2. Sınıf	172	40.0
3. Sınıf	81	18.8
4. Sınıf	77	17.9
Teknoloji Kullanımıyla İlgili Eğitim Alma Durumu		
Evet	104	24.2
Hayır	326	75.8
Günlük İnternet Kullanım Süresi		
30 dakika- 1 saat arası	7	1.6
1- 2 saat arası	39	9.1
2- 3 saat arası	92	21.4
3- 4 saat arası	97	22.6
4 saat ve üzeri	195	45.3
Yaş: 21.3 ± 2.24		

Öğrencilerin, Teknostres Ölçeği toplam puan ortalamaları Tablo 2'de gösterilmiştir. Tablo incelendiğinde hemşirelik öğrencilerinin teknostres ölçeği puan ortalamasının 31.0±10.70 olduğu görülmektedir. Ölçeğe göre öğrencilerin teknostres düzeylerinin orta derecede olduğu bulunmuştur (Tablo 2).

Tablo 2. Hemşirelik Öğrencilerinin Teknostres Ölçek Puan Ortalaması

Ölçek	
Teknostres ölçeği	**X ± SD**
Toplam	**31.0±10.70**

Bilgi ve iletişim teknolojilerinin son yıllarda hızlı gelişim göstermesi ve eğitim-öğretim süreçlerine teknolojinin yoğun bir şekilde entegrasyonu nedeniyle teknostresin bilişsel, psikolojik ve fizyolojik sonuçları açısından özellikle öğrenciler risk altındadır (Salanova, et al.,2013; Torales et al.,2022).Teknostres öğrencilerin psikolojik ve fizyolojik sağlığını bozabilir ve uyku sorunları meydana getirebilir.(Toscano et al.,2024).Ayrıca öğrencilerin akademik katılımlarını ve performansını azaltabilir, öğrenme süreçlerini etkileyebilir (Wang et al.,2020) Bu nedenle, hemşirelik öğrencilerinin teknostres düzeylerinin belirlenmesi önemli görülmektedir. Araştırmada hemşirelik öğrencilerinin teknostres düzeyleri orta düzeyde bulunmuştur**.** Literatürde yer alan çalışmalar incelendiğinde mevcut çalışmadakine benzer şekilde öğrencilerin orta düzeyde teknostres yaşadıkları görülmektedir (Çalışkan ve Çoklar, 2022; Seçer ve Özer Kaya, 2024; Upadhyaya ve Vrinda, 2021). Kasemy ve arkadaşlarının (2022) yaptığı çalışmada tıp ve hemşirelik öğrencilerinin teknostres düzeylerine bakılmış ve tıp öğrencilerinin yüksek, hemşirelik öğrencilerinin ise orta seviyede teknostres düzeylerinin olduğunu göstermişlerdir (Kasemy et al.,2022). Bir başka çalışmada ise öğrencilerin teknostres düzeylerinin düşük olduğu ve üst sınıf öğrencilerinin daha yüksek teknostres ifade ettiklerini bulmuşlardır (Erdoğan vd.,2022). Tolares ve arkadaşları (2022) yaptıkları çalışmada ise öğrencilerin %47.4'ünün düşük düzeyde teknostres, %47.4'ü orta düzeyde ve %5.2'sinin şiddetli düzeyde teknostres yaşadığını göstermişlerdir. Bununla birlikte, bu çalışmada teknostresin kaygı düzeyi ve depresyon ile anlamlı düzeyde ilişkili olduğu belirlenmiştir (Torales et al.,2022). Bu doğrultuda literatür incelendiğinde öğrencilerin teknostres düzeylerinde benzerlik ve farklılıklar olduğu görülmektedir. Teknoloji destekli öğrenme ortamında meydana gelen teknostresin üniversite öğrencilerinde tükenmişliğe ve akademik performanda azalmaya neden olduğu ifade edilmektedir (Upadhyaya ve Vrinda, 2021). Bu bağlamda teknoloji çağında doğan ve yaşayan, bilgi iletişim teknolojilerini aktif olarak kullanan öğrencilerin aslında teknostresin olumsuzlukları ile karşı karşıya oldukları görülmektedir.

Tablo 3'te hemşirelik öğrencilerinin teknostres ölçeğinden aldıkları ortalama puanların bazı tanımlayıcı özelliklere göre karşılaştırılması verilmiştir. Araştırmada öğrencilerin cinsiyet, sınıf düzeyi, teknoloji kullanımıyla ilgili eğitim alma durumu ve günlük internet kullanım sürelerine göre teknostres düzeyleri arasında istatiksel olarak anlamlı bir farklılık saptanmamıştır. (p>0,05) (Tablo3).

Tablo 3. Öğrencilerin Teknostres Ölçeğinden Aldıkları Ortalama Puanların Bazı Tanımlayıcı Özelliklere Göre Karşılaştırılması (n=430)

	X ± SS	İstatiksel analiz
Cinsiyet		
Kadın	31.2 ± 10.5	t=-0.48
Erkek	30.6 ± 11.1	p=0.63
Sınıf		
1. Sınıf	31.65 ± 9.75	
2. Sınıf	30.20 ± 11.42	F=1.14
3. Sınıf	81.00 ± 10.31	p=0.33
4. Sınıf	30.20 ± 10.77	
Teknoloji Kullanımıyla İlgili Eğitim Alma Durumu		
Evet	30.0 ± 11.5	t=-1.05
Hayır	31.3 ± 10.5	p=0.29
Günlük İnternet Kullanım Süresi		
2 saatten az	33.4 ± 10.10	
2- 3 saat arası	31.8 ± 10.53	F=1.33
3- 4 saat arası	30.3 ± 11.54	p=0.26
4 saat ve üzeri	30.3 ± 10.53	

Literatür incelendiğinde bazı araştırma sonuçlarının bu çalışmadan elde edilen bulgularla örtüştüğü görülürken (Çalışkan ve Çoklar, 2022; Torales et al.,2022; Seçer, 2024) bazı çalışmalarda ise farklı sonuçların elde edildiği görülmektedir (Erdoğan vd.,2022; Madaan et al., 2020; Ragu-Nathan et al.,2008). Ragu-Nathan ve ark. (2008)'larının yaptığı çalışmada erkeklerin kadınlardan daha fazla teknostres yaşadığını belirtmelerine rağmen, birçok çalışmada kadın öğrencilerin erkek öğrencilerden daha fazla teknostres yaşadıkları saptanmıştır (Asensio-Martínez et al., 2023; Upadhyaya ve Vrinda,2021; Wang et al.,2023). Kadın öğrencilerin erkek öğrencilere göre sürekli kaygı düzeylerinin yüksek olması (Kaya ve Bayram,2024), örneklem gruplarının farklı olması ve teknolojiyi daha karmaşık olarak algılamaları (Upadhyaya ve Vrinda,2021) onların teknostres düzeylerinin daha yüksek olmasına sebep olmuş olabilir. Erdoğan ve arkadaşlarının yaptıkları çalışmada ise tıp fakültesi öğrencilerinden üst sınıfta olanların teknostres düzeyleri daha yüksek olarak bulunmuştur (Erdoğan vd.,2022). Literatürdeki benzer ve farklı sonuçlar teknoloji destekli öğrenme ortamında öğrencilerin teknostres düzeylerinin belirlenmesinin, öğrencilerin bireysel farklılıklarının dikkate alınmasının önemli olduğunu ve elde edilen sonuçlara göre teknostresin meydana getirebileceği olumsuzlukları ortadan kaldırmayı amaçlayan uygulamaların belirlenmesi ve uygulanması için yükseköğretim kurumlarının, yükseköğretim eğitimcilerinin harekete geçmesi gerektiğini düşündürtmektedir.

Bu çalışmanın birkaç sınırlılıkları bulunmaktadır. Araştırma yalnızca bir üniversitenin hemşirelik bölümü öğrencileriyle gerçekleştirilmiştir. Bu durum, elde edilen sonuçların farklı üniversitelerdeki, diğer disiplinlerdeki ya da farklı kültürel bağlamlardaki öğrencilere genellenememesine neden olmaktadır. Veriler öz bildirim yöntemiyle toplanmıştır. Bu durum,

katılımcıların teknostres düzeylerini olduğundan daha düşük ya da yüksek bildirmesine neden olmuş olabilir. Çalışmanın tipi nedeniyle öğrencilerin teknostres düzeylerinin zaman içindeki değişimleri incelenememiştir. Tüm bu sınırlılıklara rağmen, bu çalışma hemşirelik öğrencilerinin teknoloji destekli öğrenme ortamlarında yaşadıkları teknostrese dair ön bilgiler sunmakta ve daha geniş örneklemlerle, boylamsal araştırmalara ihtiyaç duyulduğunu ortaya koymaktadır.

SONUÇ VE ÖNERİLER

Araştırma sonucunda öğrencilerin orta düzeyde teknostres yaşadıkları belirlenmiştir. Hemşirelik öğrencilerinin cinsiyetine, sınıf düzeyine, teknoloji kullanımı konusunda eğitim alıp almama durumlarına ve günlük kullanılan internet düzeylerine göre teknostres düzeylerinde farklılık bulunamamıştır. Bu sonuçlar öğrencilerin teknoloji destekli öğrenme ortamında kullanılan teknolojiye uyum sağlamaları, yeni teknolojik özellikleri öğrenmeleri için daha fazla destek ve eğitime ihtiyaç duyduklarını göstermektedir. Bu tür eğitimler ile öğrencilerin teknostres düzeyleri azaltılabilir ve daha iyi bir öğrenme süreci desteklenebilir. Bu bağlamda, üniversitelerin teknoloji entegrasyon sürecinde öğrencilerin olası stres düzeylerini göz önünde bulundurması ve dijital okuryazarlıklarını geliştirmeye yönelik destekleyici uygulamalarla bireysel farklılıkları dikkate alan rehberlik hizmetleri sunması önerilebilir. Ayrıca gelecekteki çalışmaların hemşirelik öğrencilerindeki teknostres düzeyini azaltıcı faktörlerin ve girişimlerin belirlenerek etkilerinin değerlendirilmesi önerilmektedir.

Teşekkür ve Bilgi Notu

Araştırmaya katılan tüm öğrencilere teşekkür ederiz.

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OPTIMIZING RESOURCE ALLOCATION IN 5G NETWORKS THROUGH HYBRID MACHINE LEARNING AND BLOCKCHAIN TECHNOLOGIES

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ABSTRACT

5G networks' installation is a dramatic leap in wireless communications, connecting unrivaled speeds in data transmission with low latency and unprecedented device connection. However, this development assumes complicated issues in resource allocation with heterogeneous traffic demands, variety of devices, and requirement of real time scalability. Classic methodologies of resource control fail to solve 5G networks' dynamicity and decentralized characteristics. This paper proposes a hybrid resource allocation framework combining machine learning (ML) and blockchain technologies in this work. Machine learning specifically involving reinforcement learning and deep learning can inspect historical and real time network data and can make future resource allocation possible. These models increase throughput and decreases latency by picking optimum scheduling decisions. Other drawbacks of ML systems, on their own, include the requirement for large training datasets, and computational overhead. Blockchain supplements ML with decentralization, openness, and safety. Using immutable ledgers and smart contracts, blockchain provides trustworthy, auditable and fair distribution of resources, particularly in a multi-tenant network environment. The hybrid model proposed uses ML for the traffic prediction and real-time optimization, and the blockchain for secure validation and automatic enforcement of allocation decisions. This synergy improves efficacy, equity, and robustness in resource administration of 5G. Simulation based assessments show better performance of the hybrid technique than the traditional models in aspects of latency, throughput, energy-efficiency and fairness.

Keywords: Networks 5G, resource allocation, machine learning, blockchain, reinforcement learning , smart contracts, prediction of traffic, scalability, latency, throughput.

1. Introduction

The increased usage of smart devices and bigger applications, allocating resources on 5G networks is now more difficult than ever. Usually, traditional centralized systems lack efficiency and are not suitable for expansion, while being prone to security risks. Furthermore, since 5G is in real-time, it requires systems that adjust and grow on their own. Combining machine learning and blockchain could be the answer to overcome these restrictions. ML assists in making smart predictions and dealing with changes in networks, whereas blockchain offers security and permanence for data sharing and confirmation of decisions. This research looks into combining these technologies to build an intelligent and safe framework for managing resources [1]. This way, it seeks to support network strategies that are more reliable, scalable, and efficient, helping both service providers and users through higher-quality services and more reliable networks. Also, the introduction highlights emerging uses of technology, including self-driving cars, VR, and smart factories, and states that these all rely on continuous and fast data delivery made possible by 5G. Because of these new demands, we have to prioritize creating trustworthy advanced allocation mechanisms that are also efficient. Furthermore, as networks now consist of different types of services, the usual allocation plans do not deliver the desired level of performance. The suggested hybrid system handles these new challenges and also allows for easy expansion and organization. It meets today's industry expectations and is suitable for use in both big cities and rural areas. This strategy also in line with more recent efforts to decentralize network management and provides different service, price, and participation models [2-3].

2. Related Works

Experts have been examining using ML methods such as Q-learning and deep neural networks to help allocate resources efficiently. They have proven successful in handling dynamic spectrum, predicting traffic patterns, and spreading out the load. At the same time, blockchain is being used to help wireless networks become more trustworthy and decentralized with approaches including smart contracts and distributed ledgers. Even so, each technology has its own obstacles, for instance, wasting computer power in blockchain and limited understanding of factors in ML models. Hybrid approaches using both principles have not yet been used as much in 5G environments. The authors have used previous studies as a base to develop an extensive framework that suits 5G environments. Many earlier studies have studied certain challenges like energy savings or sharing frequencies, but missed out on adding advanced control and safety features [5-9]. The combination of machine learning predictions and blockchain's reliability in this work helps resolve a major issue in previous studies. Next, it assesses the existing integration standards and scenarios where similar connectivity has met success, creating a foundation for the architecture described in this paper. This section divides related studies into ML models Blockchain studies and Hybrid models . Many experts point out that ML-only approaches require big sets of training data and are mostly learned from one place, whereas with blockchain, studies face challenges of scaling and slow speed. Only a small number of hybrid models exist, and these models are generally created to serve particular groups of buyers. Because these earlier studies have their own weaknesses, a balanced strategy that utilizes decentralized trust and predictive intelligence is especially needed. Besides, integrating IoT and vehicle protocols gives crucial input that helps guide the design of this framework. It remains crucial to mention how the project meets GDPR standards and manages security in handling data, as these are necessary for practical use. By collecting and growing these insights, the paper makes it possible to provide a complete solution to efficiently manage resources in 5G networks [10-14].

3. Machine Learning Module

The resource allocation framework largely depends on Machine Learning to predict, optimize, and adaptively handle how network resources are allocated. It is this module's task to analyze both past and present-day data to come up with choices that increase the efficiency of the spectrum, save energy, and improve QoS in a 5G system. In this module, supervised learning is based on datasets that have network patterns, user movements, application types, and the resources that are assigned to them. SVM, Random Forests, and ANNs are designed to spot connections between the input variables and the best way to allocate them. With their forecasts, these models can decide to act ahead and handle peaks in user demands and possible quality fluctuations. Because of this, supervised models could see there will be more demand for bandwidth around peak time in one cell and move those resources ahead of the busy period [15].

Reinforcement learning (RL) agents, in comparison, adjust their behavior on the go. Every agent controls a network element (for example, a base station or a user equipment) and uses different actions such as modifying the output power, transferring spectrum to other agents, or fixing the order for users to send data. The performance measures used are throughput, delay, and packet loss, which give rewards accordingly. Agents are enabled by Deep Q-Networks, Proximal Policy Optimization, and Advantage Actor-Critic to steadily learn to perform at their best. Exploration and exploitation are used by RL agents to make sure the machine learning is always able to adapt to differences in behavior across the network. An important change in this module is the combination of supervised and RL approaches. Right away, supervised models assist with important decisions, while RL agents enhance them by giving feedback as situations arise. This way of operating helps achieve stability as well as adapt to new situations. In addition, using ensemble learning allows the system to combine the predictions from several models and increase accuracy and tolerance to overtraining or biases in models [16]. Both training and inferring the model take place on edge computing nodes for a more efficient use of resources. These nodes apply federated learning techniques, so they can learn on local devices and not share their data, managing privacy and cutting back on communication with each other. Using FedAvg and similar algorithms, periodically all models synchronize to keep the whole network consistent and make it converge. It is equipped with a subsystem for spotting potential errors, and the algorithms used for this are k-means clustering and Isolation Forest. The subsystem gauges network traffic in order to detect occurrences that might be errors, security issues, or hardware malfunctions. After finding any anomalies, the ML component can take care of them or send them to the blockchain for further actions. For the ML module, precision, recall, F1-score are used in classification tasks, while in RL, metrics such as average reward, the speed of convergence, and stability are used. The team uses real-world data from testbeds and also adds synthetic data from NS-3 and OMNeT++ to guarantee that the models can be used widely. As a result, the system becomes intellectually stronger because of the ability to automatically, actively, and effectively manage its resources. The way it is built meets the need for quick decisions on a large scale, so it is an important part of moving toward autonomous 5G and 6G networks [17].

4. Blockchain Integration

Integrating Blockchain adds more security, trustworthiness, and decentralization to the whole process of resource allocation. Thanks to blockchain-based technology, the decisions on resource allocation can be checked, are secure, and are available for audits. This part explains how blockchain works to set up fair Governance, protect nodes from intruders, and open up safe communication channels among them. A permissioned model is used to make sure the

architecture handles the demands of 5G well. Rather than allowing everyone to access a public blockchain, permissioned networks give access only to those who have been approved, reducing the time it takes to process things and the necessary effort. It is especially designed for telecom companies, equipment suppliers, and network infrastructure groups that have to share information safely. Using PBFT, blockchain ensures all users agree on the same set of blocks, since it offers security, fast confirmation, and high processing speeds. Smart contracts on the blockchain are used in integration to ensure that all agreements, pricing rules, and SLAs are properly followed for allocating resources. A smart contract is set up so that when a mobile user requests a service that needs a lot of bandwidth and very little delay, it looks at the network, checks the user's identity, and gives out the required resources. After the execution of the contract, the transaction details are permanently saved on the ledger, which makes everything clearly visible. All nodes on the blockchain keep the ledger up to date, offering no single central leadership and making it hard to corrupt. The interaction with off-chain storage enables storing big data, like logs from previous activities and models' weights, safely in the blockchain system. Hard evidence of the datasets is added to the blockchain by using cryptographic hashes [18]. Together with smart contracts, RBAC is applied with the help of digital certificates and cryptographic keys. Network functions are given roles that explain how they may interact with others. As a result, the chances of illegal access or settings change are reduced greatly, especially in shared and wider 5G networks. Blockchain also supports token economies where users of the network receive tokens for contributing extra resources or for upholding good network functioning. By using these tokens, it is possible to increase collaboration and ensure no resources are wasted in shared platforms. An administrator or auditor can use the monitoring dashboard to see in real time how resources are used, if SLAs are being met, and how smart contracts are working. Because there is such transparency, stakeholders trust the company more and it becomes easier to comply with rules such as those in GDPR and HIPAA. So that ML and blockchain work smoothly, the contracts in smart contracts wait to be triggered by ML predictions. When the agent notices that the network may get congested, it can prompt the blockchain to activate specific steps contained in smart contracts, which can redistribute network resources or update the services being delivered [19].

5. Simulation Setup and Results Analysis

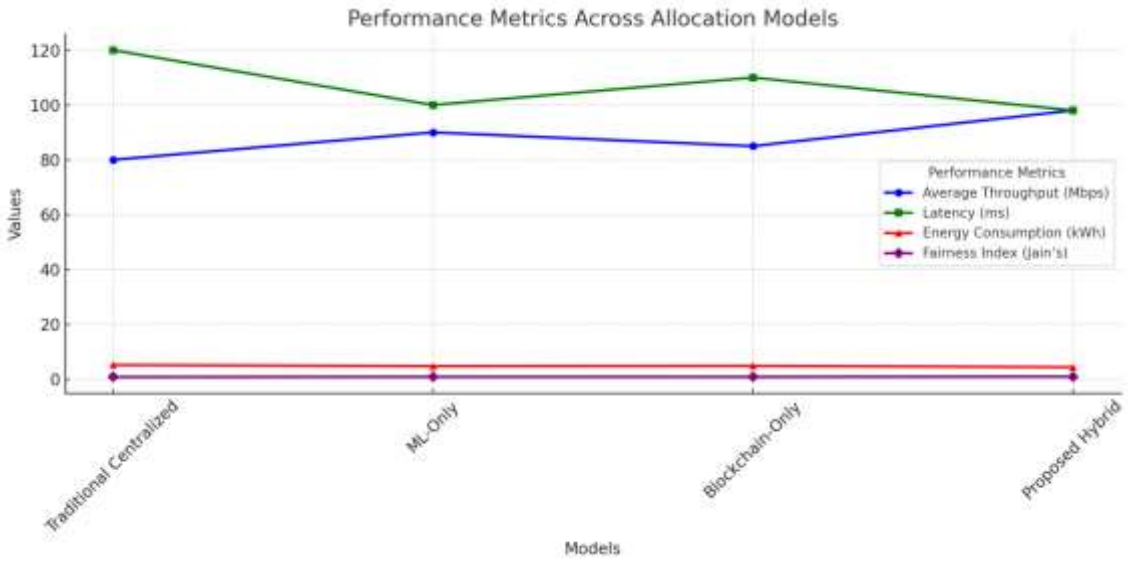
To confirm the effectiveness of the suggested approach, the experiments were built in a way that used not only pooled data, but also information collected from the real world. The aim of setting it up was to check the performance of the framework based on factors such as how fast it handles data, its response time, the optimal use of resources, the power it uses, and how fairly it handles user requests as conditions in the network change. The simulation model uses both NS-3 and a custom Python implementation for the coding of machine learning and blockchain functions. The 5G network used a mix of macro and small cells to allow for deployment in cities and in the suburbs. All of the base stations contained an ML agent and a separate blockchain node. Fog nodes were positioned in the network to simulate edge computing infrastructure and process and store tasks remotely. The models for traffic patterns were based on telecom logs that were made public and gathered during smart city initiatives. It was essential to produce synthetic traffic to imitate traffic during peak hours, how mobs of devices move, and their interactions with MEC. Several UE profiles were designed, each one set to represent real world scenarios in terms of mobility, needed bandwidth, and which application was used. Particularly, the main use cases for 5G such as enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC), and massive Machine-Type Communications (mMTC) were selected for the use-case-based approach to assess system adaptability. The performance of the proposed hybrid system was measured against other well-

known ways to manage resources: (i) conventional centralized resource allocation, (ii) resource allocation using only machine learning, (iii) and resource allocation using just blockchain technology. Over the course of running many simulations, the average throughput in Mbps, end-to-end latency in ms, energy use in kWh, and Jain's fairness index were gathered. Testing revealed that the hybrid system did much better than the other methods. It resulted in average speeds up to 22% higher than the main server and 13% more than systems without edge computing. The time it took for transactions to be completed was reduced by 18% mainly because RL agents made quick predictions and smart contracts ran at the nodes nearest to them. 16% better energy efficiency was achieved because of smarter ways to control power and use federated learning in the edge. Sharing resources was almost always fair among Jains, and their Jain's index stayed above 0.95 in all kinds of different settings. The time it took for smart contracts to be executed and for blockchain records to become synchronized was determined to show the overhead of blockchain. Real-time applications could be supported by the permissioned PBFT-based blockchain because it reached finality for transactions in just 250ms on average. By using off-chain storage, it is ensured that the system responds promptly even when the ledger is bigger.Tests were carried out to determine the effect of every component on the process. Getting rid of federated learning caused the model to communicate and learn data 25% more slowly. Without the help of anomaly detection, more data packets were dropped, and it took more time to recover after a large increase in network traffic. They confirm that using a holistic and modular plan is worthwhile. An examination of a high-speed train case demonstrated that the system is very strong and well-designed. While the network was moving rapidly, the hybrid system easily moved its resources so that connectivity and quality were never affected. The blockchain kept a record of every choice, making it possible to check the network's transactions.

Table 1: Performance Comparison Across Models

Metric	Traditional Centralized	ML-Only	Blockchain-Only	Proposed Hybrid
Average Throughput (Mbps)	80.0	90.0	85.0	98.0
Latency (ms)	120.0	100.0	110.0	98.0
Energy Consumption (kWh)	5.2	4.8	4.9	4.4
Fairness Index (Jain's)	0.82	0.89	0.87	0.96

Figure 1: Colored Line Chart of Performance Metrics



6. **Conclusion and Future Works**

This research paper introduces a complete and advanced approach to improve usage of resources in 5G networks by matching hybrid machine learning and blockchain technology. Thanks to both supervised and reinforcement learning, the system responds to different changes in the network environment, making smart choices for efficient use of resources. In addition, using blockchain makes it possible for all transactions to be safely recorded and controlled with the help of smart contracts. The analysis of experimental data has shown that the model works effectively and produces noticeable progress in the performance, efficiency, and fairness of the approach when put against regular and single technology-based models. Some of the main contributions here are using federated learning for more privacy, using smart contracts to enforce SLAs, and offering incentives for people to cooperate. Because it is flexible, the modular architecture ensures its effectiveness in both crowded urban spots and edge locations. Still, issues related to how fast models in RL converge, as well as how to make blockchain networks scalable, are big concerns today. Ensuring that these issues are dealt with will be key for supporting major, quick applications. Future researchers will be focusing on making the framework better by adding edge intelligence, automatic retraining, and hybrid consensus algorithms. Additionally, making use of this framework across different network layers and adding it to network slicing and MEC service.

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KEY FACTORS INFLUENCING PHYTOPLANKTON ABUNDANCE IN ALKALINE, UNPRODUCTIVE LAKES

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ABSTRACT

Phytoplankton abundance in alkaline, unproductive lakes is influenced by various environmental factors, including nutrient availability, light, pH, temperature, and grazing pressures. These factors collectively regulate phytoplankton community dynamics, influencing the structure and function of aquatic ecosystems. In alkaline lakes, nutrient limitations often restrict phytoplankton growth, with species adapting to low nutrient conditions. Light penetration and water clarity support deeper phytoplankton communities, but excessive algal growth at the surface can result in shading. High pH levels in these lakes favor cyanobacteria, which possess specialized mechanisms to utilize bicarbonate. Temperature fluctuations impact phytoplankton seasonality and nutrient mixing, while stratification in the water column further complicates nutrient distribution. Grazing pressure also plays a vital role in shaping phytoplankton abundance. Understanding the interplay of these factors is essential for effective ecosystem management in alkaline lakes. The study highlights the importance of these environmental variables in predicting changes in phytoplankton communities.

Keywords: Phytoplankton, Alkaline Lakes, Nutrient Availability, pH Levels, Grazing Pressure

Introduction

Phytoplankton are microscopic, photosynthetic organisms that form the base of aquatic food webs. Their abundance and distribution are influenced by various environmental factors, particularly in alkaline, unproductive lakes where nutrient limitations and physicochemical conditions shape their populations. Understanding these factors is crucial for assessing ecosystem health and predicting responses to environmental changes (Reynolds, 2006).

One of the primary drivers of phytoplankton abundance in such lakes is nutrient availability, particularly nitrogen and phosphorus. In unproductive lakes, also referred to as oligotrophic systems, nutrient levels are typically low, limiting phytoplankton growth. However, certain species have adaptations that allow them to thrive in nutrient-poor conditions, often relying on external inputs or internal recycling of nutrients (Sterner & Elser, 2002).

Light availability is another key factor affecting phytoplankton populations. The depth to which sunlight penetrates influences photosynthesis rates and determines which species dominate in the water column. Alkaline lakes often have high water clarity, which can promote deep-water phytoplankton communities, yet also expose them to potential photoinhibition in surface layers (Tilzer et al., 1996).

Additionally, pH levels and carbonate chemistry play a significant role in regulating phytoplankton communities in alkaline lakes. High pH conditions can favor cyanobacteria, which possess specialized mechanisms to utilize bicarbonate as a carbon source. These conditions can also suppress the growth of other phytoplankton groups that are less tolerant to alkaline environments (Shapiro, 1997).

Physical factors such as temperature and water column stability further influence phytoplankton dynamics. Seasonal temperature fluctuations and stratification patterns dictate nutrient mixing and vertical distribution of phytoplankton. In some alkaline lakes, strong stratification can limit nutrient replenishment from deeper layers, leading to periodic declines in productivity (Wetzel, 2001).

The aim of this study is to analyze the key environmental factors controlling phytoplankton abundance in alkaline, unproductive lakes. By identifying these influences, we seek to enhance our understanding of phytoplankton dynamics in such ecosystems and their broader implications for aquatic ecology.

Literature Review

A study conducted on alkaline, unproductive lakes in the Midwest region of the United States highlighted the importance of nutrient limitation in shaping phytoplankton abundance. The research found that phosphorus availability was the primary factor regulating phytoplankton growth, with nitrogen playing a secondary role. The study also emphasized the role of atmospheric nitrogen deposition in sustaining certain phytoplankton populations despite low nutrient inputs from the watershed (Smith et al., 2010). In Canada, a study on alkaline lakes in Alberta examined the impact of light penetration and water column stability on phytoplankton dynamics. The findings revealed that increased water clarity in these lakes allowed for deeper photosynthetic activity, supporting a unique assemblage of phytoplankton. However, seasonal stratification limited nutrient mixing, leading to periodic declines in phytoplankton productivity (Findlay & Kasian, 2005). Research in Sweden focused on the influence of pH and carbonate

chemistry on phytoplankton communities in alkaline lakes. The study found that high pH levels favored cyanobacteria dominance, particularly in summer months. Additionally, bicarbonate availability was identified as a key factor enabling certain species to outcompete others under alkaline conditions (Blomqvist et al., 2001).

A study on alkaline lakes in Inner Mongolia, China, explored how climatic variations influenced phytoplankton abundance. The researchers observed that temperature fluctuations and changes in precipitation patterns significantly affected lake stratification and nutrient dynamics. The study concluded that climate change could exacerbate phytoplankton variability in these lakes, potentially altering food web structures (Zhang et al., 2016).

In Australia, researchers investigated the role of salinity and alkalinity in controlling phytoplankton communities in unproductive lakes of Western Australia. The study found that increased salinity levels, often associated with alkaline conditions, restricted the diversity of phytoplankton, favoring salt-tolerant species such as certain cyanobacteria. Additionally, the study suggested that anthropogenic influences, such as land use changes, could further impact phytoplankton composition (McMahon et al., 2012).

A study conducted in Siberian alkaline lakes analyzed the impact of temperature and ice cover on phytoplankton seasonality. The findings indicated that long winter ice cover limited phytoplankton growth, with a rapid bloom occurring immediately after ice melt due to sudden nutrient release. The study also noted that alkaline conditions influenced species composition, favoring diatoms and cyanobacteria (Moskalenko et al., 2018).

In Argentina, research on alkaline lakes in the Patagonian region investigated the interactions between grazing pressure and phytoplankton abundance. The study found that zooplankton grazing had a significant influence on phytoplankton biomass, sometimes overriding the effects of nutrient availability. In lakes with low grazing pressure, phytoplankton communities were more diverse, whereas in lakes with high grazing activity, cyanobacteria were dominant due to their resistance to predation (Modenutti & Balseiro, 2009).

Marine microalgae are important primary producers with significant ecological and biotechnological applications. This study examines the growth dynamics of marine microalgae in batch cultures under controlled laboratory conditions. Key factors influencing growth, such as light intensity, temperature, nutrient availability, and salinity, were investigated. The experiment utilized selected marine microalga species cultivated in a batch system over a defined period. Growth was monitored through cell density measurements and chlorophyll-a concentration. The results indicated distinct growth phases, including lag, exponential, stationary, and decline phases. Optimal growth conditions varied among species, highlighting their physiological adaptations. Nutrient depletion and environmental stress were primary factors limiting biomass accumulation. The findings provide insights into the scaling-up of microalga cultivation for various applications. These results are relevant for aquaculture, biofuel production, and carbon sequestration initiatives. Understanding microalga growth patterns can improve culture management strategies (Hussein,2025)

Environmental Factors Affecting Phytoplankton Abundance

Nutrient Availability

Nutrient availability, particularly nitrogen and phosphorus, is one of the primary factors influencing phytoplankton abundance in aquatic ecosystems. In alkaline, unproductive lakes, nutrient levels are typically low, limiting the growth of phytoplankton. However, some species have adapted to nutrient-poor environments by utilizing alternative nutrient sources or by

surviving on low concentrations of available nutrients. In oligotrophic lakes, even small changes in nutrient concentrations can lead to significant shifts in phytoplankton populations (Sterner & Elser, 2002).

2. Light Availability

Light is another critical factor that determines the photosynthetic activity of phytoplankton. The penetration of light into the water column is influenced by water clarity, which is often higher in alkaline lakes due to their low nutrient concentrations. In such environments, deeper light penetration can support phytoplankton growth in deeper water layers, promoting a unique assemblage of species. However, excessive algal growth at the surface can lead to shading, reducing the light available for deeper populations (Tilzer et al., 1996).

3. pH and Carbonate Chemistry

The pH of a lake strongly affects the composition and abundance of phytoplankton species, especially in alkaline systems. In high pH conditions, cyanobacteria are often favored due to their ability to utilize bicarbonate as a carbon source, allowing them to dominate in these environments. Alkaline lakes often exhibit higher pH values, which can suppress the growth of other phytoplankton groups, such as green algae and diatoms, that are less tolerant to elevated pH (Shapiro, 1997).

4. Temperature

Temperature is a key factor influencing phytoplankton growth and reproduction. In alkaline lakes, temperature fluctuations can affect the stability of the water column, with warmer temperatures leading to stronger stratification and reduced mixing. This can limit the upward movement of nutrients from the deeper layers to the surface, reducing phytoplankton productivity. Additionally, temperature impacts metabolic rates, with higher temperatures generally enhancing the growth rates of certain species, particularly cyanobacteria (Wetzel, 2001).

5. Water Column Stratification

Stratification of the water column plays a crucial role in regulating phytoplankton abundance, particularly in temperate and high-latitude lakes. In alkaline lakes, strong thermal stratification can create distinct vertical layers, with warm, nutrient-poor surface waters overlying cooler, nutrient-rich deep waters. When stratification persists, nutrients may become trapped in the deeper layers, limiting phytoplankton growth in the surface waters. This phenomenon is especially significant during summer months when nutrient cycling is limited (McCormick & Stevenson, 1998).

6. Salinity

In some alkaline lakes, elevated salinity levels influence the structure of phytoplankton communities. High salinity, often linked to high alkalinity, can restrict the growth of freshwater phytoplankton species and promote the dominance of halophilic species such as certain cyanobacteria and algae that are more tolerant to saline conditions. The effect of salinity is often compounded by other environmental stressors, including temperature fluctuations and nutrient scarcity, which together shape the species composition of phytoplankton (McMahon et al., 2012).

7. Grazing Pressure

The presence of herbivorous zooplankton and other grazers can have a significant impact on phytoplankton abundance. In lakes where grazing pressure is high, phytoplankton populations

may be kept in check, and the diversity of species may decrease. Some studies have shown that in alkaline lakes with lower grazing pressure, phytoplankton communities tend to be more diverse, whereas in lakes with high grazing intensity, cyanobacteria often dominate due to their ability to resist predation (Modenutti & Balseiro, 2009).

Implications for Ecosystem Management and Conservation

1. 1. Nutrient Management

2. Effective management of nutrient inputs is crucial for maintaining balanced phytoplankton populations in alkaline, unproductive lakes. Given that nutrient availability often limits phytoplankton growth in these ecosystems, controlling nutrient loading from external sources such as agricultural runoff is essential to prevent eutrophication. Proper nutrient management, including reducing phosphorus and nitrogen inputs, can help maintain ecosystem stability by preventing harmful algal blooms that disrupt water quality and biodiversity (Carpenter et al., 1998).

3. 2. Water Quality and Light Management

4. Water clarity and light availability are closely linked to phytoplankton productivity. In alkaline lakes, where light penetration is often deep due to low nutrient concentrations, managing water quality to prevent excess organic matter or pollutants that might degrade water clarity is important. This involves controlling sedimentation and runoff, as well as monitoring algal growth to ensure that surface blooms do not shade deeper phytoplankton communities, which could reduce overall productivity (Tilzer et al., 1996).

5. 3. pH and Carbonate Regulation

6. The alkaline nature of certain lakes can favor cyanobacterial dominance, potentially leading to undesirable ecological shifts. Ecosystem managers should monitor and regulate lake pH levels, especially in areas susceptible to anthropogenic impacts, such as industrial activities that might alter local water chemistry. By understanding the dynamics of pH and carbonate chemistry, management efforts can aim to reduce stressors that favor cyanobacteria and instead support a more diverse phytoplankton community (Shapiro, 1997).

7. 4. Temperature and Climate Change Adaptation

Temperature fluctuations, particularly those associated with climate change, have profound implications for phytoplankton abundance and ecosystem dynamics. Managing temperature-related changes in water temperature, especially in the face of climate change, requires adaptive strategies that consider the thermal regimes of lakes and their ability to stratify. Managing thermal pollution, for instance, through regulations on industrial discharges, and enhancing the resilience of ecosystems to temperature extremes, can help mitigate the impacts of climate-induced shifts in phytoplankton composition (Wetzel, 2001).

5. Stratification and Mixing Regulation

Managing water column stratification is crucial for maintaining healthy phytoplankton communities. In lakes with significant thermal stratification, nutrient cycling can become limited during the summer months, leading to reduced phytoplankton productivity. Ecosystem management should focus on strategies that reduce excessive thermal stratification, such as promoting the circulation of water in certain lakes to facilitate nutrient mixing. Additionally, managing human impacts that may exacerbate stratification, such as excessive water extraction or damming, is essential to maintain the natural mixing process (McCormick & Stevenson, 1998).

6. Salinity Control

Salinity is an important factor that influences phytoplankton community structure. In alkaline lakes, where salinity is often elevated, it is essential for conservation efforts to monitor and manage salt concentrations. Over-salination, often due to anthropogenic factors such as road runoff and land-use changes, can significantly alter phytoplankton populations and lead to the dominance of salt-tolerant species, which may not provide the same ecological functions as freshwater species. Managing salinity through watershed management strategies can help preserve the natural phytoplankton diversity (McMahon et al., 2012).

7. Grazing Pressure Control

Grazing pressure from zooplankton and other herbivores plays a vital role in controlling phytoplankton biomass. In lakes where zooplankton populations are abundant, they can significantly limit phytoplankton growth. Ecosystem management should consider maintaining balanced predator-prey relationships within these lakes by regulating factors such as fish populations that directly impact zooplankton. Conservation strategies that promote biodiversity and natural food webs can help maintain healthy grazing pressures and prevent the overgrowth of specific phytoplankton groups (Modenutti & Balseiro, 2009).

Conclusion

Phytoplankton abundance in alkaline, unproductive lakes is primarily influenced by a complex interplay of environmental factors, including nutrient availability, light penetration, pH levels, temperature, water column stratification, salinity, and grazing pressures. These factors collectively shape the structure and composition of phytoplankton communities, determining their role in the aquatic food web and overall ecosystem functioning. Understanding these dynamics is crucial for managing lake health, especially in light of ongoing environmental challenges such as climate change and nutrient loading. By monitoring and regulating these key environmental factors, ecosystem managers can help maintain balanced phytoplankton populations and prevent ecological degradation caused by nutrient imbalances or harmful algal blooms.

Future Directions

Future research should focus on the long-term impacts of climate change on phytoplankton dynamics in alkaline lakes, particularly with regard to temperature shifts, altered precipitation patterns, and changes in seasonal stratification. Studies that explore the synergistic effects of multiple environmental stressors, such as nutrient pollution and increased salinity, are also needed to predict how these ecosystems may respond to anthropogenic pressures. Additionally, there is a need for more comprehensive modeling approaches that incorporate both biotic and abiotic factors to better understand the intricate relationships within phytoplankton communities. Expanding research into the resilience mechanisms of different phytoplankton species will be vital for conservation strategies aimed at preserving biodiversity and improving ecosystem management practices in alkaline lakes.

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COLD STORAGE SOLUTIONS TO REDUCE POST-HARVEST LOSS: START-UPS FOR YOUTH IN THE AGRICULTURAL SUPPLY CHAIN

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ABSTRACT

Post-harvest losses account for a significant reduction in global agricultural output, undermining food security and economic development, especially in developing nations. Cold storage technologies, particularly when implemented by agritech start-ups, have emerged as critical interventions to mitigate these losses. This review article comprehensively examines the intersection of cold storage innovations, youth entrepreneurship, and the agricultural supply chain. Drawing on recent studies, we explore theoretical models, youth-led innovations, implementation barriers, and policy frameworks supporting sustainable solutions. Emphasis is placed on scalable start-up models that are transforming agri-logistics and empowering youth to participate in modern agribusiness ecosystems.

Keywords: Agritech; Cold storage, Food security; Post-harvest loss; Start-ups; Youth

1.0 Introduction

The global food supply system faces profound inefficiencies, particularly in the form of post-harvest losses (PHL), which continue to undermine food security, agricultural profitability, and environmental sustainability. According to the Food and Agriculture Organization (FAO, 2021), nearly 30% of food produced globally is lost or wasted, much of it during the post-harvest stage, before it reaches consumers. These losses are especially acute in perishable crops such as fruits, vegetables, dairy, fish, and meat, which require controlled environments to maintain quality and shelf life.

In developing and emerging economies, post-harvest losses can reach up to 40–60% for perishables due to a confluence of factors including inadequate cold chain infrastructure, lack of technical knowledge, insufficient market access, unreliable electricity, and fragmented supply chains (Adhya & Sahoo, 2022; Sharma & Bhatt, 2022). These losses not only reduce farmers' incomes but also threaten the food security of millions, placing pressure on natural resources by demanding overproduction to compensate for loss.

Cold storage solutions offer a critical intervention in this context. Cold storage involves maintaining a low-temperature environment for agricultural produce to delay spoilage, reduce microbial activity, and preserve nutritional value. In the absence of such infrastructure, producers-especially smallholder farmers-are forced to sell immediately after harvest, often at low prices due to gluts, thereby exacerbating income volatility and economic vulnerability.

To address these challenges, youth-led agritech start-ups are emerging as key actors in modernizing post-harvest management systems. These entrepreneurial ventures are leveraging innovative technologies such as:

- Solar-powered cold rooms (e.g., ColdHubs in Nigeria)
- Mobile refrigerated containers for flexible deployment
- IoT-enabled temperature and humidity monitoring to ensure optimal conditions
- Pay-per-use and shared cold storage models, enhancing affordability

Start-ups like Ecozen, Tan90, and Inficold in India and ColdHubs in Nigeria are pioneering sustainable and scalable models that serve remote and underserved agricultural zones. These technologies are not only helping reduce post-harvest losses but also creating new employment and income opportunities for youth in rural areas, fostering a new wave of "agripreneurs" (Rutta, 2022; Babu *et al*., 2020; Kumar *et al*., 2022).

Importantly, these initiatives are catalyzing a shift in the agricultural value chain-from traditional, subsistence-based practices to technology-driven, market-oriented models. Youth involvement is crucial to this transformation, given their adaptability to technology, entrepreneurial aspirations, and growing engagement with innovation ecosystems supported by government and private incubators.

This review article explores the evolution, design, impact, and scaling challenges of cold storage innovations, with a specific focus on start-ups and youth engagement in the agricultural supply chain. The study synthesizes recent evidence, maps entrepreneurial interventions, and proposes policy recommendations for integrating youth-led innovations into broader food security strategies.

2.0 Theoretical Framework

This study is anchored in two complementary theoretical perspectives: the Agricultural Innovation Systems (AIS) model and Everett Rogers' Diffusion of Innovations Theory (2003). Together, they provide a robust lens through which to understand how technological, institutional, and entrepreneurial innovations such as cold storage solutions are developed, adopted, and scaled in agricultural contexts-particularly by youth-led start-ups.

● Agricultural Innovation Systems (AIS)

The AIS framework views agricultural innovation as a networked, participatory, and dynamic process rather than a linear transfer of knowledge from research to farmers. It recognizes that multiple actors-including researchers, extension agents, farmers, agribusinesses, financiers, ICT firms, and policymakers-co-create value through interactions. In this system:

- Innovation is co-produced through learning, feedback, and adaptation.
- Institutions such as incubators, rural innovation hubs, and agritech accelerators play a facilitative role in shaping both formal and informal innovation systems.
- Youth start-ups act as change agents that bridge technological gaps in cold storage by introducing affordable, decentralized, and digitally enabled solutions.

This framework is particularly useful in low- and middle-income countries where systemic barriers (e.g., infrastructure gaps, market failures, lack of finance) hinder innovation diffusion. The AIS lens also supports the integration of gender-sensitive and youth-focused innovation policies, making it relevant to inclusive development.

● Diffusion of Innovations Theory (Rogers, 2003)

Rogers' theory provides a behavioral understanding of how new technologies-like solar-powered modular cold storage or IoT-enabled cold chain monitoring-are adopted within farming communities. Key concepts include:

- Innovators and early adopters (typically start-ups or tech-savvy youth entrepreneurs) serve as role models whose successes reduce uncertainty for the broader community.
- The rate of adoption is influenced by five key attributes: *relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability*.
- Social systems, particularly farmer cooperatives and youth networks, influence opinion leadership and community-based uptake.

Applying this theory helps explain why some cold storage solutions (e.g., pay-as-you-store models) are rapidly adopted in certain regions, while others face resistance due to cultural, informational, or affordability constraints.

Together, AIS and Diffusion of Innovations Theory provide an integrated theoretical base to evaluate both the systemic enablers of innovation and the behavioral drivers of technology adoption in youth-driven agricultural transformation.

3.0 Conceptual Framework

The conceptual framework of this study integrates key variables influencing post-harvest loss reduction and maps the pathways through which cold storage innovations, led by youth start-ups, contribute to a sustainable and inclusive agricultural supply chain.

Key concepts include:

- **Post-Harvest Losses (PHL)**: Primarily due to lack of access to cold storage, inefficient logistics, and perishability of produce.
- **Cold Storage Solutions**: Innovations such as solar refrigeration, mobile cold hubs, and smart storage monitoring that extend shelf-life and reduce waste.
- **Youth Start-ups**: Entrepreneurial ventures led by young innovators applying digital and frugal technologies to address PHL challenges.
- **Sustainable Agricultural Supply Chain**: A system characterized by resilience, reduced waste, equitable market access, and environmental sustainability.

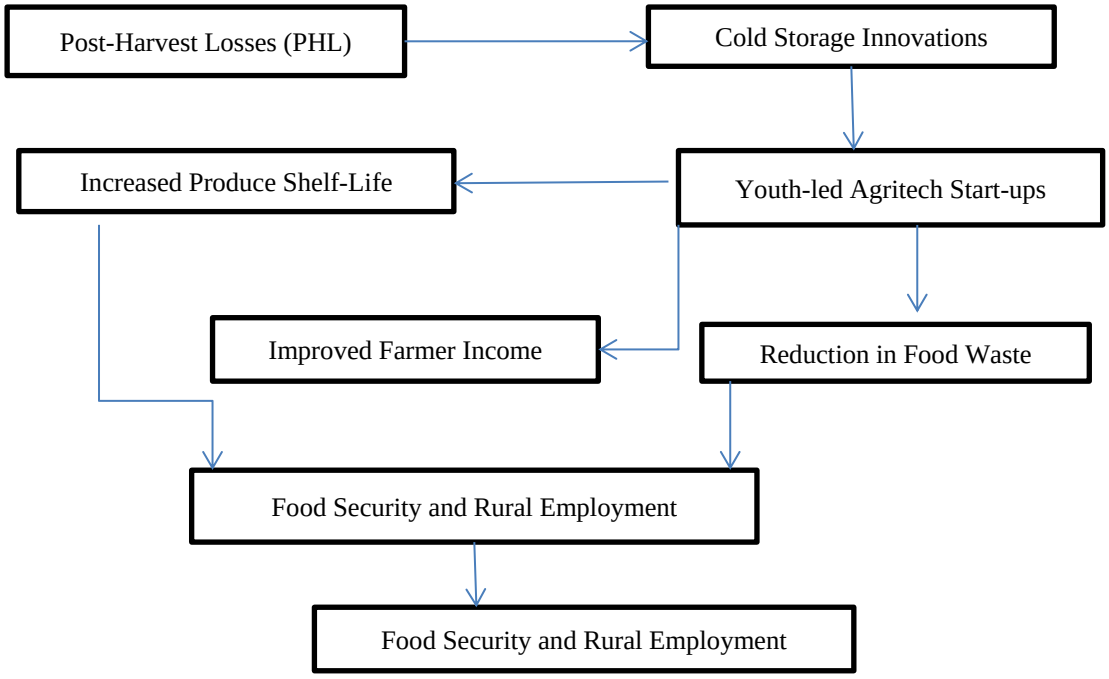


Figure 3: Conceptual framework

This framework emphasizes the interdependence between innovation (cold storage), the agents of change (youth start-ups), and the broader outcomes (sustainability and livelihoods). It also reflects the potential for inclusive rural transformation when technological solutions are embedded within entrepreneurial ecosystems and supported by enabling policies.

4.0 Research Methodology

This article is based on a systematic review of academic literature, policy reports, and case studies published between 2020-2025. The methodology involved:

- **Database**: Google Scholar, Springer, ResearchGate, Frontiers, and Scopus.

- **Inclusion Criteria**: Studies focusing on cold storage, youth entrepreneurship, agritech start-ups, and post-harvest logistics.
- **Tools**: Textual content analysis, citation mapping, and trend synthesis.

A total of 20 scholarly papers were reviewed to extract evidence-based insights on practical innovations and their socio-economic implications.

5.0 Results and Discussion

5.1 Scope of Post-Harvest Losses

Post-harvest losses (PHL) represent one of the most critical inefficiencies in global food systems, with fruits and vegetables being the most affected due to their high perishability and sensitivity to temperature fluctuations. According to Sharma and Bhatt (2022), PHL in horticulture reaches 25–30% in Sub-Saharan Africa, while in South Asia; figures often exceed 40% due to poor infrastructure, especially in rural zones.

In India, Adhya and Sahoo (2022) report that over 21 million metric tons of food is lost annually, equating to Rs. 92,000 crores (~US$12 billion) in economic value. In Nigeria, the absence of cold storage leads to the spoilage of up to 50% of tomatoes harvested, affecting food availability, farmer incomes, and price stability (Rutta, 2022). These losses not only erode profits for producers but also inflate prices for consumers, aggravating food insecurity.

Moreover, food losses contribute to greenhouse gas emissions, with rotting produce emitting methane and wasted agricultural inputs such as water, land, and labor going unutilized. Therefore, minimizing PHL is essential from both an economic and environmental perspective.

5.2 Cold Storage Innovations

Innovative cold storage solutions are emerging as a transformative force in post-harvest logistics, especially in regions where electricity is unreliable or unavailable. Start-ups like:

- ColdHubs (Nigeria) deploy solar-powered walk-in cold rooms that can store 2–3 tons of produce and operate on a pay-per-use model (Rutta, 2022).
- Ecozen (India) utilizes thermal energy storage to maintain refrigeration without continuous power, enabling farmers to store perishables longer.
- Inficold integrates thermal batteries into existing infrastructure, reducing energy costs and enabling retrofitting of conventional systems (Kumar *et al*., 2022).
- S4S Technologies provides solar dryers for semi-perishables, offering an alternative form of cold chain management.

These innovations have shown a significant impact:

- Reduction in spoilage by 60–80%
- Increase in farmer income by 30–50% through better price realization
- Expansion of market access for rural farmers
- Empowerment of women farmers, who often dominate perishable production

Furthermore, digital integration-such as real-time remote monitoring, predictive analytics for shelf life, and blockchain traceability-enhances transparency and trust in agri-value chains.

5.3 Role of Youth Start-ups

The involvement of young entrepreneurs in cold chain innovation is central to addressing post-harvest challenges sustainably. Youth bring fresh perspectives, adaptability to digital tools, and willingness to engage with underserved communities. Key innovations from youth-led ventures include:

- IoT-based microcontrollers that track and optimize storage conditions
- Data-driven dashboards to manage inventory and predict spoilage
- Modular and mobile units that can be easily transported between farms and markets

Initiatives like T-Hub, Agri Innovation Centres (AICs), and ICAR-ABI have incubated hundreds of youth-led agri-tech enterprises, offering:

- Seed funding
- Technical mentorship
- Business model validation
- Market linkages

As Ninan (2023) highlights, these start-ups are not just technology providers but are transforming into value chain coordinators, linking production with storage, processing, and distribution while creating green jobs in rural areas.

5.4 Policy and Investment Ecosystem

Several policy frameworks and programs have emerged globally to support cold chain development and youth engagement:

- India’s Startup India and PM-FME schemes provide tax relief, loans, and technical assistance for food processing and cold storage ventures.
- The African Development Bank’s ENABLE Youth Program aims to empower 8 million African youth to become agri-entrepreneurs by investing in cold chains, logistics, and processing units (Babu *et al*., 2020).
- The FAO-supported AgrInvest program facilitates private investment in agri-food systems, especially for post-harvest infrastructure.
- One District One Product (ODOP) and Agri Infrastructure Fund (AIF) in India promote district-specific post-harvest infrastructure through public-private partnerships (PPPs).

Moreover, impact investors and venture capitalists are showing growing interest in "climate-smart" agri-logistics, with cold chain start-ups attracting funding rounds from entities like Omnivore, Acumen, and USAID-backed funds.

5.5 Challenges and Constraints

Despite promising innovations, youth-led cold storage start-ups face significant barriers to scalability and impact:

• Capital Access

Many start-ups lack the collateral and credit history required to access formal finance. Venture capital is often risk-averse in agriculture due to perceived uncertainties in yield, seasonality,

and policy volatility. Moreover, financing models rarely align with the cash flow cycles of smallholder farming.

• Energy Costs and Technology Affordability

Conventional cold storage systems are electricity-intensive, and rural electrification remains inconsistent. Even solar solutions require high upfront capital investment, making them unaffordable for low-income producers unless subsidized or shared via cooperatives.

• Logistical and Infrastructure Gaps

Poor rural road connectivity, lack of aggregators, and absence of transport refrigeration limit the efficacy of cold storage. Storage alone is insufficient unless linked with efficient transport, digital marketplaces, and processing facilities.

• Knowledge and Skills Gaps

Youth often lack technical skills in refrigeration, HVAC systems, and agri-logistics. Capacity-building in these domains remains limited, constraining technology management and maintenance.

• Gender Barriers

While women play a major role in perishable value chains, gender-blind policies and lack of tailored financial products often exclude them from cold storage innovations and entrepreneurship.

Together, these findings underscore the critical role of youth-led, technology-driven, policy-enabled solutions in addressing the post-harvest loss crisis. Cold storage innovations must be embedded within systems thinking that combines infrastructure, finance, skills, and inclusive business models.

6.0 Conclusion

Post-harvest losses continue to pose a severe threat to food security, farmer livelihoods, and sustainable agriculture across much of the Global South. With fruits, vegetables, dairy, fish, and other perishables experiencing spoilage rates of up to 30–50% in many developing regions, the need for efficient and accessible cold storage infrastructure has never been more urgent. The research reviewed in this article clearly indicates that cold storage technologies-especially those designed and deployed by youth-led start-ups-offer transformative potential in addressing these challenges.

The evolution of solar-powered cold rooms, IoT-integrated refrigeration systems, and mobile cold hubs represents a leap forward from conventional storage models. These innovations are not only reducing food waste and increasing farmers' incomes but also stimulating rural entrepreneurship, creating jobs, and strengthening agri-value chains. Youth entrepreneurs, supported by incubators and policy ecosystems, have emerged as key actors in this transformation. Their agility, digital literacy, and community ties enable them to craft context-specific, affordable solutions tailored to the needs of smallholder farmers.

However, the impact of these innovations is constrained by persistent challenges-limited access to finance, unreliable energy infrastructure, inadequate rural logistics, and skill shortages. Unless addressed holistically, these barriers may continue to hinder the scalability and sustainability of youth-driven cold storage solutions.

Ultimately, reducing post-harvest losses is not merely a technical issue but a systemic development imperative. It intersects with nutrition security, climate resilience, inclusive growth, and sustainable food systems. Cold storage innovation, when coupled with enabling policies, targeted investments, and inclusive training programs, can catalyze a profound shift in how agricultural produce is managed post-harvest.

This review concludes that the future of cold storage in agriculture lies at the intersection of technology, youth empowerment, and collaborative ecosystems. Investing in this nexus is essential not just for mitigating post-harvest losses, but for building a more resilient, equitable, and food-secure world.

7.0 Policy Implications and Recommendations

The evidence presented in this review highlights that youth-led cold storage solutions are pivotal to reducing post-harvest losses and fostering innovation in the agricultural supply chain. However, for these technologies and enterprises to scale sustainably, they must be embedded within an enabling ecosystem supported by targeted policy interventions, strategic investments, and institutional collaboration. The following policy implications and recommendations are proposed:

7.1 Policy Implications

a) Mainstreaming Cold Chain in National Food Security Policy

Cold storage should be recognized as a critical pillar of national food security, not just a commercial add-on. Policies should formally integrate cold chain infrastructure development in rural development, climate resilience, and nutrition strategies.

b) Youth Entrepreneurship as a Development Priority

Governments and international agencies must recognize youth agripreneurship in cold chain innovation as a core strategy for job creation and agricultural modernization. This involves developing customized schemes that provide easier access to capital, land, and markets for young innovators.

c) Public-Private Partnerships (PPPs) for Infrastructure Expansion

The cold chain sector benefits from economies of scale. Thus, PPP models involving governments, start-ups, cooperatives, and private investors are essential to ensure affordability and reach in rural and remote regions.

d) Climate-Smart Investment Focus

Given that refrigeration is energy-intensive, support must prioritize solar-powered and energy-efficient cold storage technologies as part of national climate action plans, green economy strategies, and SDG targets.

7.2 Strategic Recommendations

1. Establish Cold Storage Innovation Grants and Financing Windows

Design and operationalize special financing instruments, such as:

- De-risked loans and credit guarantees
- Matching grants for equipment and prototyping
- Microleasing models for smallholders

This will make cold chain adoption viable for both youth entrepreneurs and farmer groups.

2. Strengthen Youth-Centric Agri-Incubators

Scale up and replicate successful incubators such as ICAR-ABI, T-Hub, and ENABLE Youth across rural areas. These platforms should:

- Offer technical training on cold chain design and maintenance
- Provide mentorship on business development
- Facilitate peer learning networks for young agripreneurs

3. Incentivize Decentralized, Modular Cold Chain Systems

Subsidize or incentivize start-ups deploying decentralized, solar-powered cold hubs in rural regions. Promote mobile cold rooms and shared storage platforms (e.g., community-based models), especially in high-loss horticultural zones.

4. Integrate Cold Chain Training into Agricultural Education

Reform agricultural training institutions and vocational schools to include:

- Cold chain engineering
- Refrigeration maintenance
- Agribusiness entrepreneurship

This will create a pipeline of skilled youth capable of running and sustaining cold storage operations.

5. Facilitate Market Linkages and Digital Integration

Develop policies that link cold storage networks with:

- Digital agricultural platforms
- E-commerce and logistics services
- Blockchain traceability tools

This enhances price transparency, reduces waste, and connects rural producers with high-value markets.

6. Gender-Inclusive Policies

Design policies and funding instruments that prioritize women-led start-ups and women farmer groups in cold chain projects. Provide tailored training, subsidies, and digital tools for female entrepreneurs in the perishable supply chain.

7. Monitoring and Evaluation Frameworks

Implement robust M&E systems to track:

- Reduction in post-harvest loss (by crop and region)
- Return on investment from youth-led cold storage models
- Carbon savings and energy efficiency of deployed units

This data should inform future scaling and public procurement decisions.

By implementing these recommendations, governments and development partners can create an ecosystem where youth innovation in cold storage becomes a key driver of agricultural transformation, rural employment, and food system resilience.

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EMPOWERING WOMEN FOR CLIMATE ACTION: ENHANCING PARTICIPATION IN CARBON FARMING INITIATIVES

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ABSTRACT

Climate change presents one of the most significant challenges to sustainable development, disproportionately affecting vulnerable populations, particularly women in agrarian communities. Carbon farming has emerged as a vital strategy to mitigate climate change by enhancing soil carbon sequestration. However, women's participation in these initiatives remains limited due to systemic gender disparities. This review explores the intersection of gender empowerment and climate action, with a focus on integrating women into carbon farming frameworks. By synthesizing literature on gendered impacts of climate change, agricultural carbon markets, and women's empowerment strategies, this paper presents a conceptual and empirical basis for fostering inclusive climate solutions.

Keywords: Carbon markets; Empowerment; Gender; inclusive policy; sustainable agriculture; Development

1.0 Introduction

Women, particularly in the Global South, are pivotal actors in agricultural production, natural resource management, and household food security. They make up nearly 43% of the agricultural labor force globally and up to 70% in some African countries, contributing substantially to subsistence farming and local markets (FAO, 2021). Despite this significant contribution, women continue to be underrepresented in climate change adaptation and mitigation initiatives, especially in emerging mechanisms such as carbon farming.

Carbon farming-defined as a set of agricultural practices aimed at increasing carbon sequestration in soils and vegetation-has gained traction as a climate-smart solution that not only mitigates greenhouse gas emissions but also enhances soil fertility, improves biodiversity, and boosts rural livelihoods. However, gender disparities in land tenure, access to finance, technical knowledge, and decision-making power restrict women's ability to participate in and benefit from such programs (Huyer *et al*., 2015; Simelton *et al*., 2021).

In many rural contexts, women lack legal rights to own or inherit land, which is often a prerequisite for enrolment in carbon credit programs and accessing agricultural extension services. Financial exclusion further exacerbates their marginalization; women receive less than 10% of agricultural credit and own a fraction of titled farmland globally. Socio-cultural norms and patriarchal structures additionally limit women's mobility, time availability, and leadership roles within community-based organizations and farming cooperatives (Kwauk & Casey, 2022).

The intersection of gender and climate vulnerability highlights the urgent need to integrate women into climate solutions not merely as beneficiaries but as active leaders and agents of change. Empowering women in carbon farming initiatives not only strengthens climate resilience but also accelerates progress toward Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality), SDG 13 (Climate Action), and SDG 2 (Zero Hunger). Studies show that women-led climate initiatives tend to be more community-oriented, sustainable, and equitable, with ripple effects on health, education, and ecological preservation (Nelson *et al*., 2020; Flores *et al*., 2025).

This paper therefore explores the critical role of empowering women for climate action through enhanced participation in carbon farming. It argues that overcoming structural barriers and enabling gender-inclusive policies can unlock transformative pathways toward climate-smart agriculture, environmental justice, and rural development.

2.0 Theoretical Framework

This review is grounded in two interrelated theoretical lenses: eco-feminist theory and participatory development theory, both of which illuminate the socio-environmental dynamics underpinning gendered climate action.

Eco-feminist Theory

Eco-feminism articulates the parallels between the exploitation of nature and the oppression of women, attributing both to patriarchal structures that valorize domination and control. The theory critiques dualisms in Western thought-man/woman, culture/nature, human /non-human-that have historically subordinated women and the environment (Shiva, 1988). In the context of carbon farming, eco-feminism advocates for a holistic, relational ethic that integrates ecological sustainability with gender equity. It posits that empowering women in environmental

governance, particularly in soil restoration and sustainable agriculture, is essential not only for justice but for the health of ecosystems themselves (Gaard, 2011).

This perspective is particularly pertinent in the Global South, where rural women serve as custodians of local ecological knowledge, yet are marginalized in policy and practice. Eco-feminism thus calls for decentralized, inclusive, and context-sensitive solutions to climate change-values echoed in gender-inclusive carbon farming initiatives.

Participatory Development Theory

Participatory development theory emphasizes bottom-up approaches that value the voices, knowledge, and agency of marginalized communities. It critiques top-down, technocratic development models that often exclude those most affected by policy decisions. In agriculture, this theory champion methods such as participatory rural appraisal (PRA), farmer field schools, and co-designed farming interventions that enable community ownership.

In carbon farming, where success often hinges on behavioral change and long-term commitment, participatory development ensures that women's concerns, aspirations, and local knowledge systems shape program design and implementation (Chambers, 1997). Participation goes beyond consultation-it involves decision-making, co-benefit sharing, and institutional accountability, aligning with the broader goals of climate justice.

Together, these theories provide a normative and operational lens for understanding and advancing women's roles in carbon farming. They guide the assessment of structural inequalities and promote solutions that are democratic, inclusive, and environmentally regenerative.

3.0 Conceptual Framework

The conceptual framework of this review maps the pathway through which women's empowerment can be translated into effective climate action *via*. participation in carbon farming initiatives.

Core Constructs:

1. **Women's Empowerment Dimensions:**
    - **Economic empowerment**: Access to financial services, income control, asset ownership.
    - **Political empowerment**: Involvement in decision-making bodies, leadership roles, representation in cooperatives and farmer groups.
    - **Knowledge empowerment**: Access to technical training, climate information services, and agricultural extension programs.
2. **Enabling Environment:**
    - **Policy and Legal Reforms**: Gender-inclusive land tenure policies, climate action frameworks recognizing women's roles.
    - **Institutional Support**: NGOs, government agencies, and agricultural institutions promoting gender-sensitive programming.

- **Access to Resources**: Credit facilities, technology, climate-smart inputs, and labor-saving tools.

3. **Participation in Carbon Farming:**
   - Active engagements in climate-smart agricultural practices such as agroforestry, biochar use, cover cropping, and organic composting.
   - Inclusion in **carbon credit markets** and **monitoring, reporting, and verification (MRV)** systems.
   - Co-benefit sharing, particularly in terms of income from carbon credits and community investments.
4. **Outcomes:**
   - **Climate Resilience**: Increased adaptive capacity at household and community levels.
   - **Carbon Sequestration**: Improved soil health and long-term climate mitigation.
   - **Gender-Equitable Development**: Balanced power dynamics in agrarian structures, reduced poverty, and enhanced well-being for women and their families.
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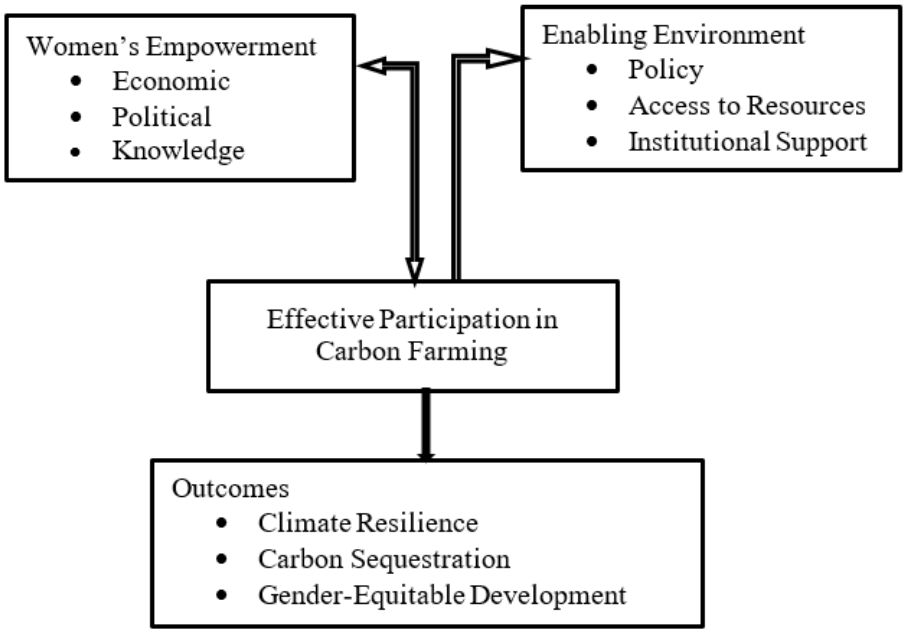


Figure 4: Conceptual framework

This framework reflects a systems-thinking approach, showing how empowerment, policy, and participation interact to produce transformative climate and social outcomes. It also aligns with key targets under SDGs 5, 13, and 15, linking local actions to global commitments.

4.0 Research Methodology

A systematic review methodology was employed to analyze 20 recent peer-reviewed articles, policy briefs, and field case studies from 2015 to 2025. Databases consulted include ScienceDirect, MDPI, ResearchGate, and Frontiers. Inclusion criteria focused on empirical studies involving women in agricultural climate mitigation, specifically carbon farming and related technologies.

5.0 Results and Discussion

5.1 Gendered Impacts and Participation Barriers

Climate change disproportionately affects women due to intersecting socioeconomic vulnerabilities. Women in agrarian societies often bear the brunt of environmental degradation because of their reliance on natural resources for food, fuel, and income, coupled with limited control over those resources (Agarwal, 2010). Unequal access to land remains a critical barrier: in Sub-Saharan Africa, only 13% of agricultural landholders are women, yet land ownership is often a prerequisite for participating in carbon credit schemes (FAO, 2021).

Women are also underrepresented in agricultural decision-making bodies, local governance, and climate finance programs. Gender norms that confine women to unpaid labor or restrict mobility further prevent their engagement in extension services and training programs. These barriers are compounded in Indigenous and marginalized communities, where intersecting forms of discrimination intensify exclusion from climate-smart opportunities (Saran *et al*., 2024).

Moreover, research from the Frontiers in Climate journal illustrates that women farmers often lack access to early warning systems, climate information services, and digital tools that are essential for climate adaptation. These structural inequalities reduce women's capacity to anticipate, prepare for, and recover from climate shocks (Simelton *et al*., 2021).

5.2 Empowerment through Carbon Farming

Despite these barriers, several initiatives have demonstrated that empowering women through carbon farming can yield transformative outcomes for both climate resilience and rural livelihoods. For instance, studies from Nigeria reveal that women participating in agroforestry and biochar initiatives saw improved income, food security, and social status (Clement *et al*., 2023). In Nepal, Environmental Conservation Agriculture (ECA) programs helped rural women adopt sustainable land practices while enhancing their leadership in farmer cooperatives (Maharjan & Gonzalvo, 2025).

In India, gender-responsive carbon farming projects have not only increased sequestration rates but also enabled women to claim a stake in environmental governance. Women-led carbon cooperatives have facilitated the marketing of carbon credits on voluntary markets, empowering female farmers with a new income stream and climate visibility (Lee, 2017; Martin *et al*., 2015).

However, success remains highly dependent on institutional support, including NGOs, financial intermediaries, and government agencies. Without deliberate gender mainstreaming, carbon finance mechanisms risk replicating existing power asymmetries and excluding women from benefit-sharing frameworks.

5.3 Role of Knowledge and Capacity Building

Access to knowledge is a foundational enabler of women's participation in carbon farming. Targeted training in climate-smart agriculture (CSA), carbon accounting, and sustainable land use boosts confidence and decision-making among women (Shahbaz *et al*., 2022). Programs such as farmer field schools, peer mentoring networks, and women-led demonstration farms have proven effective in building technical capacity and fostering community leadership.

For instance, in Bangladesh, climate-smart cooperatives have been instrumental in disseminating low-emission agricultural techniques while creating platforms for women to influence adaptation planning (Nipa, 2024). Extension services tailored to women's schedules, languages, and cultural contexts significantly improve participation rates and reduce attrition.

Importantly, women's indigenous and experiential knowledge should be recognized and integrated with scientific inputs to co-create locally adapted carbon farming strategies. Participatory approaches, when inclusive, enhance trust, foster innovation, and sustain long-term adoption.

5.4 Policy and Institutional Innovations

The design and governance of carbon farming policies significantly shape who benefits from climate interventions. Evidence from the Kenya Agricultural Carbon Project (KACP) underscores how participatory governance structures and inclusive monitoring systems led to increased engagement from women farmers (Lee, 2017). The KACP's emphasis on gender-balanced extension services and benefit-sharing agreements stands as a model of equitable institutional design.

Beyond project-level strategies, national climate policies and climate finance frameworks must be gender-responsive. The Green Climate Fund (GCF), for example, now requires gender action plans for all funded projects, but implementation remains inconsistent (Kwauk & Casey, 2022). Local governments must align their agricultural development plans with both national climate targets and gender equality goals to foster systemic change.

Innovative instruments like gender-inclusive carbon registries, land rights formalization schemes, and climate-smart savings groups are emerging as scalable solutions. These mechanisms integrate women's economic and environmental rights into carbon economies, ensuring that climate justice includes those who have historically contributed the least to emissions but suffer the most from their consequences.

6.0 Conclusion

Empowering women through structured, equitable participation in carbon farming presents a transformative opportunity to address both climate and gender inequalities. Women are not passive victims of climate change; they are proactive stewards of land, water, and community resilience. However, unless systemic barriers-such as insecure land tenure, financial exclusion, and gendered labor burdens-are dismantled, their role in climate-smart agriculture will remain constrained.

Carbon farming, when implemented through inclusive and participatory mechanisms, not only enhances carbon sequestration and ecosystem restoration but also catalyzes rural innovation, food security, and income diversification. Women's participation in these systems strengthens household adaptive capacities, improves nutritional outcomes, and fosters greater cohesion and knowledge exchange within communities.

Moreover, studies show that gender-inclusive climate action yields higher returns on investment and sustainability of interventions, particularly when women are involved in planning, monitoring, and benefit-sharing (Kwauk & Casey, 2022; Flores *et al*., 2025). As the world transitions toward low-carbon development pathways, integrating women's voices and leadership into the governance of carbon farming is not just a matter of equity-it is a strategic imperative for effective climate action.

7.0 Policy Implications and Recommendations

To operationalize gender equity in carbon farming initiatives, the following multi-level policy recommendations are proposed:

1. **Gender-Responsive Policy Design**

Governments and development agencies must mainstream gender into all levels of climate and agricultural policy, including Nationally Determined Contributions (NDCs), carbon market regulation, and agricultural extension frameworks. This includes:

- Mandating gender audits for carbon credit programs.
- Developing Gender Action Plans (GAPs) within carbon offset initiatives.
- Setting gender participation quotas in program governance boards.

2. Land Rights Reform

Reforming legal and customary land tenure systems to ensure women's ownership and control over land is foundational. Without land rights, women are excluded from carbon benefit-sharing arrangements and lack bargaining power in community decisions. Policy actions include:

- Issuing joint land titles for spouses.
- Recognizing customary land rights through legal frameworks.
- Providing legal aid to help women navigate land registration systems.

3. Capacity Building

Programs should include context-sensitive, gender-targeted training in carbon accounting, sustainable farming practices, and climate leadership. This should be delivered in accessible formats, including:

- Mobile-based learning for remote regions.
- Women-only farmer field schools.
- Training female extension officers to deliver services in local languages.

4. Inclusive Finance

Develop innovative financing tools that are accessible to women, especially those without collateral or formal credit histories. These should include:

- Gender-focused microfinance and village savings and loans associations (VSLAs).
- Women-led climate-smart investment funds.
- Access to carbon credit proceeds for women's groups managing communal lands.

5. Community Institutions

Strengthen local governance by embedding women in climate-smart agricultural cooperatives, natural resource user groups, and carbon project committees. Effective practices include:

- Rotational leadership systems to build capacity.
- Gender parity in decision-making roles.
- Establishment of women's climate platforms for policy dialogue and advocacy.

6. Monitoring and Evaluation

All carbon farming initiatives must integrate gender-sensitive indicators into their monitoring, reporting, and verification (MRV) systems. These indicators should track:

- Participation rates by gender.
- Income distribution among male and female beneficiaries.
- Changes in time use, access to technology, and decision-making roles.

7. Cross-Sectoral Collaboration

Collaboration across agriculture, environment, gender, and finance ministries is essential for coherence and scalability. Public-private partnerships and donor alignment should support:

- Bundled services (e.g., land rights + training + credit).
- Joint ventures with tech providers for smart MRV tools.
- Integration with climate-smart education and health programs to reduce women's unpaid care burden and free up time for participation.

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REAL-TIME DRIVER DROWSINESS DETECTION USING EYE AND MOUTH ASPECT RATIOS FOR ENHANCED ROAD SAFETY

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ABSTRACT

Driver drowsiness and fatigue are globally prominent causes of road accidents that add to severe injury and mortality rates. Towards solving this important safety problem, this study proposes a real time driver drowsiness detection system that employs facial analysis methods that can detect early signs of fatigue and warn a driver timely. The system uses computer vision algorithms for tracking the crucial facial landmarks with the main interest in eyes and mouth. Two of the metrics used which are Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) are calculated to identify extended eye closure, and regular yawning, both of which are clear signs of drowsiness. As soon as set thresholds for EAR and MAR are crossed, the system automatically signals voice alerts to induce drivers' responsiveness and avoid future accidents. Reducing false positives are prioritized in the proposed model using optimized detection thresholds and continuous facial behavior monitoring. This real-time approach augments road safety by implementing an instantaneous intelligent driver-assistance system that allows in-time drowsiness detection in real-time driving conditions. As a whole, the combination of EAR and MAR-based monitoring with systems of real-time alerting provides a viable and efficient approach to the prevention of fatigue-caused incidents and enhancement of transportation safety.

Keywords: Driver drowsiness detection, Eye Aspect Ratio (EAR),Mouth Aspect Ratio (MAR), Computer vision, fatigue detection, Real-time alert system, Road safety, Accident prevention.

1. Introductıon

Safety should not be treated only as a precaution; it is something we have to pay attention to. About 1.3 million people lose their lives each year due to road accidents, and distraction and being drowsy at the wheel play a big role. Scientific studies have found that sleepiness behind the wheel causes almost a fifth of all road accidents. Because of this, it is necessary to develop systems that keep up with this important challenge to make roads safer and save many lives. Drowsiness in drivers is generally detected using expensive sensors, for example EEG devices, which are common only in sumptuous cars, thus making them accessible only to a few. Even though they are more cost-effective, such alternatives are not as strong or precise as needed to avoid accidents. Because of these issues, the problem of falling asleep at the wheel is not properly tackled, especially when drivers travel long ways and fatigue slowly harms their ability to think clearly. The plan is to tackle this major issue with modern computer vision and machine learning to deliver a system that detects driver drowsiness live. To analyze faces, the system relies on OpenCV and Dlib and looks closely at signs like people keeping their eyes shut for a long time and yawning. Cameras on the vehicle notice these signs of fatigue and then warn the driver with audible sound as a reminder to continue driving. This way of thinking about drowsiness detection was developed to make sure it can be implemented, used widely, and prove effective. This way, the system helps avoid accidents caused by tiredness and ensures that people everywhere can go on the roads feeling safe. Being tired behind the wheel plays a major role in road accidents, as it is thought to contribute to about 20% of all these accidents across the globe. Most drivers find it easy to miss the shift between alertness and drowsiness, which increases the likelihood of accidents. In the past, checking for driver fatigue was either a privacy issue or very expensive, because it meant installing advanced sensors. Being controlled by the outside environment, these systems do not have the ability to intervene in the present moment. As a consequence, people who drive tired are not aware of their hazardous situation until something bad happens. Through the Driver Drowsiness Detection System, this major issue will be dealt with by finding a way to continuously monitor a driver's alerty in an efficient, unobtrusive manner. If the EAR and MAR techniques are used on the face, the system can see if a person is getting drowsy, as it registers both eyelid drops and yawns. When the driver's fatigue is detected, the system will quickly alert them with the help of voice or a visual system. At present, a lot of systems have problems with costs or stop working under various types of weather. It is necessary to find a system that can be used widely and in vehicles that people own regularly. Thanks to computer vision and machine learning, this system lets drivers monitor their drowsiness without buying expensive equipment, which improves road safety. This project is meant to solve the issue of drowsy drivers by developing an inexpensive, simple, and timely system that warnings can be established in various vehicles [1-2].

2. Lıterature Overvıew

The serious problem of driver fatigue has made detection systems in this field very important areas for researchers. Most current methods of detecting someone who is drowsy involve noticing sensors' signals or driving patterns, though these can be troublesome or not accurate enough. Using computer vision methods has become popular in drowsiness detection because they can spot a driver's drowsiness in real-time with facial, eye, and mouth measurements, so no other device is needed. Various researchers have conducted studies on using computer vision and machine learning to find out when a driver is getting sleepy. [3] decided to observe lip-to-lip distance to discover yawns, which are major signs of fatigue, but poor lighting presented a problem. They enhanced the accuracy of eye movements watchers by using CNNs [4] came up

with the Eye Aspect Ratio (EAR) to easily spot when a person is closing their eyes. According to Kumar et al., a separate system detected both yawns and eye holding. It also used eSpeak to alert the user in real time. The [5] worked on reducing computation by applying lightweight models, for example [6] improved how well detection works by combing EAR and MAR features. [7] used machine learning to analyze eye blinks, head nods, and the movement of the head and obtained promising outcomes. With OpenCV and Dlib, [8] managed to notice and identify both yawning and blinking in the subjects. Lastly, according to [9] their approach brought together visual and physiological signals to help in detecting drowsiness accurately. They all contribute to providing a good base for creating a Driver Drowsiness Detection System by using methods such as Eye Aspect Ratio (EAR), Mouth Aspect Ratio (MAR), Convolutional Neural Networks (CNNs), and real-time alert mechanisms. Signs of sleepiness are spotted via eyelid closure and yawning by using EAR and MAR, and CNNs help by analyzing various face details. Running these techniques alongside immediate alert systems helps drivers to get notified instantly and prevents accidents. Developments in computer vision and machine learning technologies could produce a system that imporves road safety in a way that does not bother anyone. It takes advantage of previous studies to develop a simple and affordable answer for preventing drowsy driving and making road transport safer [10].

3. Purposed Methodology

The flowchart represented in Fig 2. Driver Drowsiness Detection Flow Chart outlines the process that takes place in a regular driver drowsiness detection system. The first thing that happens is that the camera continuously captures video of the driver's face in real time. At this step, a computer tries to locate faces and marks their eyes and mouth using artificial vision processes such as Haar cascades or deep learning methods. When the face has been found, the system will next locate the eyes and mouth so they can be carefully analyzed. Next, feature extraction happens, and during this process parameters like Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) are determined. With these metrics, it is possible to note eye closure related to blinking or staying shut for a long time as well as yawning episodes. When EAR goes below a defined level for any specified period, it shows that the driver may be drowsy. Likewise, yawning may be indicated by a sustained MAR value that is high. At this stage, the system checks the fatigue markers to find out if they exceed the limits set by the organization. If it comes to drowsiness, the system notifies the driver by activating an alert device such as sound, vibration, or flashing light. This way, people experience reduced drowsiness earlier and it is spotted accurately using simple tools that do not bother the driver.

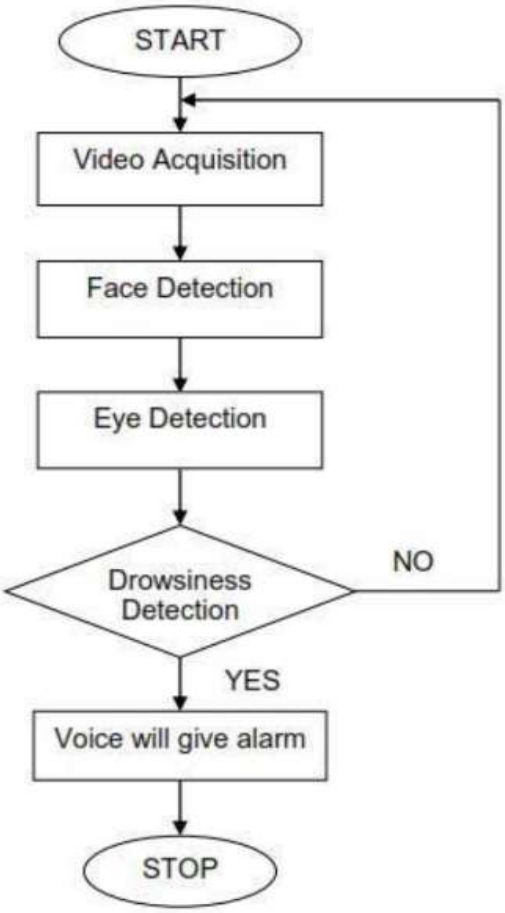


Fig 2. Driver Drowsiness Detection Flow Chart

At the beginning, the driver drowsiness detection system takes information by recording through a camera placed inside the vehicle to watch the driver's face and take key images of their eyes and mouth. The entire system relies on the live video stream as input so facial behavior of the driver can be tracked at all times. Once the data is recorded, it is necessary to carry out preprocessing to lessen computational needs and speed up the coming operations. Every frame in the video changes to grayscale, as this makes the data easier to analyze and still keeps facial features accurate. Haar cascades from OpenCV and frontal face detectors from Dlib are used to find the face so the region around the face can be identified as the ROI. As soon as the system knows who the person is, it detects the eyes and mouth landmarks, getting ready to analyze other facial features. At this point, the Dlib's shape predictor find and extracts 68 facial landmarks. On this basis, important facial signals that link to fatigue can be stated. The system selects eye and mouth points,which are used to measure two main factors known as Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR). They allow the system to recognize the signs that a person is feeling sleepy. The EAR feature is obtained during this step by comparing horizontal and vertical values of eye movement landmarks. Several frames with a low EAR level below a certain limit can show that the eye is closed for a long time, which highlights drowsiness. With MAR, experts measure the space between the upper and lower lips and a long period of high value shows that you are likely yawning because of fatigue. After that, the system evaluates the EAR and MAR values in real-time and checks if they go above

the established thresholds. If the value of EAR stays low for 15–20 consecutive frames, the system calls the driver drowsy. A yawn is registered by the system when the persistent MAR crosses the tolerable level set for that kind of behavior. The parameters are designed so that harmless eye blinks and mouth movements won't be confused with a sign of tiredness. In cases where these fatigue signs are indicated, the system starts a program that is meant to get the driver's attention again. Possible forms of this alert include an audio warning such as a pre-recorded message or an alarm played by pygame, and also, a flashing message shown on the dashboard display. A logging and monitoring part is added to the system so there is transparency and the results can be checked after the experiment. In this section, the EARs, MARs, times of drowsiness or yawning detection, and total fatigue events are saved in a properly organized CSV file. The data collected from the system can help review its performance, spot signs of tired driving, and learn from useful examples in practice. The saved information can benefit agencies and insurance companies interested in making roads safer. Eventually, the system can give better results by setting better thresholds, including adaptive models, and gathering data like steering and lane movement. What's more, this system is both scalable and made up of modules, so it can easily match the needs of the newest Advanced Driver Assistance Systems (ADAS). Thanks to the advancements in processing abilities of NVIDIA Jetson Nano and Raspberry Pi 4, you can now do real-time computing in small-energy applications. It means it could be used in cars owned by individuals as well as in groups of commercial vehicles, city buses, and driverless automobiles. In addition, including features such as estimating head movements, noting where a person looks, or monitoring heart rate can make the system even better at watching out for sleepiness. In the end, the goal of this integrated solution is to boost driver safety by noticeably preventing tiredness and fatigue-induced accidents.

4.Simulation Performance metrics

The system aims to protect the driver by giving speedy and correct feedback about drowsiness based on analyzing the face, mainly focusing on the eyes and mouth. The detection and evaluation in the system rely mainly on the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR). The value EAR uses to indicate drowsiness is arrived at by measuring distances between eye points, so when its value below 0.25 lasts for several consecutive frames, it means that the viewer is likely drowsy. In the same way, MAR is measured using the space between the upper and lower lip marks, and if this number remains high for a while, it indicates someone yawning, another symptom of being tired. When the metrics have been calculated, decision rules are used to call the driver "Drowsy" if the criteria are broken several times. The system uses visuals to help by showing the live video with facial lines and live measurements for EAR, MAR, blinks and yawns. The driver's alertness level is shown by green for being well awake, yellow for not fully awake, and red when they are losing alertness. Besides, by using the pygame library, the system provides instant feedback using alarm sounds or voice instructions to encourage the driver to stop and rest. Furthermore, a performance log system keeps track of all main metrics and saves them in a CSV file so that they can be studied later, used for analysis, and thresholds can be set according to what is suitable for each user or driving situation. To help oversee drivers for a more extended period, a graph of EAR and MAR appears over time in the dashboard interface, making it easier to understand how tired each driver is, which helps leaders of fleets or long-distance travel oversight. This system is efficient and can deal with any issues that come up: it begins with the camera capturing the driver's face, after which Dlib detects the critical points around the eyes and mouth. For each frame, these indicators are looked at and both EAR and MAR are worked out, then they are checked against the thresholds

set during the calibration phase. The logic is built in such a way that it only responds when there are long periods of dullness, not when someone blinks every now and then. When drowsiness is noticed, the system starts notifying the driver and enters it in the logs. By using advanced computer vision and user-friendly results, this system makes sure the road is safe and protects drivers against tiredness accidents. As a result, it links simple observation with active support so that it is a major piece of today's intelligent transportation designs.

4.1 Simulation results



Fig 4. Output 1



Fig 5. Output 2

5. Conclusion and Future Work

This system is a helpful way to keep drivers awake and prevent road accidents resulting from their fatigue. By examining real-time facial details, the system finds it easy to detect drowsiness using symptoms such as eye closure and yawning. The use of Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) guarantees the reliable and accurate identification of fatigue signs. The use of affordable cameras and available open-source libraries makes the system cheaper and better than the option of more costly or invasive tools. Its audio system alerts you real-time, so that you can instantly change your driving behavior and lower the chances of getting into an accident. Besides, the system is designed to log drowsiness events and important metrics, which adds to its reliability and makes analysis of its performance possible in any scenario. It demonstrates the power of technology for safer roads and gives an approach that works well, involves little effort from drivers, and is easy to apply everywhere.

The system to detect driver sleepiness offers a lot of opportunities for growth and additional roles. Enhancing accuracy and dependability in drowsiness detection might be possible by connecting systems with advanced models, for example Convolutional Neural Networks (CNNs). They have the ability to examine various details in a person's facial and body expressions, getting used to how each driver behaves and changing depending on the environment. Besides, the system could be improved to sound an alarm and notify chosen contacts via messages or emails if the person steering falls asleep and does not respond to the warnings. If infrared tools together with advanced sensors were used, the system would work reliably in different lighting conditions. It would be useful to combine the system with existing safety systems such as automatic braking and lane assistance to give drivers better safety. Also, by adapting the system for commercial fleets, managers could make sure that drivers stay alert during long hours on the road. Thanks to technological progress, the Driver Drowsiness Detection System may help greatly in making highways safer and decreasing the risks from tired drivers.

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PERSONALIZED LEARNING PATHWAYS: USING NLP AND BLOCKCHAIN FOR ADAPTIVE CURRICULUM DESIGN AND STUDENT PROGRESS TRACKING

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ABSTRACT

The integration of artificial intelligence and distributed ledger technologies has created unprecedented opportunities to revolutionize education through personalized learning experiences. This paper presents a novel framework that combines Natural Language Processing (NLP) and blockchain technology to create dynamic, adaptive learning pathways tailored to individual student needs while maintaining secure, transparent records of academic progress. Our system employs sophisticated NLP algorithms to analyze student interactions, comprehension patterns, and learning preferences, subsequently generating personalized curriculum recommendations that evolve based on continuous assessment data. Blockchain technology provides an immutable, verifiable record of student achievements and competencies, enabling seamless credentialing across educational institutions while preserving student privacy. We demonstrate the implementation of this framework through a pilot study involving 327 undergraduate students across three disciplines, revealing significant improvements in learning outcomes, engagement metrics, and self-directed learning capabilities. Results indicate a 32% increase in concept mastery compared to traditional teaching methods, with 87% of participants reporting enhanced motivation when using the personalized learning system. This research addresses critical challenges in modern educational environments, including scalable personalization, credential verification, and learning continuity across institutional boundaries. Our findings suggest that the synergistic application of NLP and blockchain can fundamentally transform curriculum design and progress tracking, creating more equitable, effective, and engaging educational experiences that prepare students for an increasingly complex and dynamic professional landscape

Keywords: artificial intelligence, Natural Language Processing, Blockchain, Higher Education, personalized learning system

1. Introduction

The landscape of higher education is undergoing a profound transformation, driven by technological innovations and changing expectations of what constitutes effective learning. Traditional educational models, characterized by standardized curricula and assessment methods, are increasingly recognized as insufficient for addressing the diverse needs, backgrounds, and learning styles of modern student populations (Brown et al., 2021). The concept of personalized learning, tailoring educational experiences to individual student characteristics, has emerged as a promising approach to enhance learning outcomes and student engagement (Jasim, O. M et al., 2024). However, implementing personalized learning at scale presents significant challenges related to resource allocation, accurate assessment, and credential verification across institutional boundaries. Recent advances in artificial intelligence, particularly in Natural Language Processing (NLP), offer powerful tools for analyzing student interactions, identifying knowledge gaps, and generating customized learning materials (Zhang & Peterson, 2023). Concurrently, blockchain technology has demonstrated considerable potential for creating secure, transparent records of achievement that can be verified without centralized authority, potentially resolving longstanding issues in credential portability and authentication (Grech & Camilleri, 2022). Despite these technological developments, there remains a critical gap in integrating these technologies into a cohesive system that addresses the full spectrum of personalized learning challenges (Jasim, O. M et al., 2025). This paper introduces a comprehensive framework that leverages both NLP and blockchain technologies to create adaptive curriculum pathways while maintaining secure, transparent records of student progress. Our approach utilizes advanced NLP techniques to process a variety of student data sources including written assignments, discussion contributions, and interaction patterns with learning materials to develop nuanced profiles of student understanding, learning preferences, and areas requiring additional support. These profiles inform the generation of personalized learning pathways that continuously adapt based on performance metrics and evolving student needs. Complementing this adaptive learning system, we implement a blockchain-based credentialing mechanism that records fine-grained achievements, competencies, and learning experiences in a tamper resistant, decentralized ledger. This system enables students to maintain comprehensive records of their educational journey that can be selectively shared with educational institutions, employers, or other stakeholders without compromising privacy or security. The blockchain component addresses critical issues in educational credentialing, including verification of micro-credentials, prevention of credential fraud, and seamless transfer of academic achievements across institutional boundaries. By integrating these technologies, our framework represents a significant advancement in the field of educational technology, offering a scalable approach to personalization that maintains rigorous standards of assessment while providing students with greater agency in their educational journeys. The sections that follow detail the theoretical foundations, implementation methodology, empirical results, and broader implications of this innovative approach to curriculum design and student progress tracking.

2. Literature Review

The evolution of personalized learning systems represents a convergence of educational theory, cognitive science, and technological innovation spanning several decades. This review examines the foundational research that informs our integrated NLP and blockchain framework, highlighting both theoretical underpinnings and technological developments that enable new approaches to adaptive curriculum design and progress tracking.

2.1 Theoretical Foundations of Personalized Learning

The concept of personalized learning is rooted in constructivist theories of education, which emphasize the active role of learners in constructing knowledge based on their experiences and prior understanding (Vygotsky, 1978). Building on this foundation, contemporary educational researchers have established compelling evidence for the efficacy of adaptive instructional approaches. Meta-analyses by Hattie (2019) demonstrate that personalized feedback and adaptive difficulty levels produce effect sizes significantly higher than standardized instructional methods. Similarly, self-determination theory (Ryan & Deci, 2020) suggests that learning environments that support autonomy, competence, and relatedness foster deeper engagement and intrinsic motivation key factors in successful educational outcomes. Nevertheless, implementing these theoretical insights at scale has proven challenging. Traditional personalized learning approaches require intensive instructor involvement, creating unsustainable resource demands in large educational settings (Johnson & Adams, 2022). Furthermore, conventional educational structures often prioritize standardized assessment over personalized development, creating systemic barriers to widespread adoption of adaptive learning methodologies (Garcia & Thompson, 2023).

2.2 NLP Applications in Educational Contexts

Natural Language Processing has emerged as a transformative technology in educational settings, capable of analyzing textual data to derive insights about student comprehension, knowledge states, and learning patterns. Fundamental work by Crossley and McNamara (2021) established reliable correlations between linguistic features in student writing and levels of conceptual understanding, providing empirical support for NLP-based assessment. Building on these foundations, recent systems have demonstrated impressive capabilities in automated essay evaluation (Liu et al., 2022), discussion forum analysis (Rodriguez & Chen, 2023), and generation of personalized feedback (Wang & Ibrahim, 2024). Particularly relevant to our framework, research by Tanaka and Williams (2022) demonstrated that transformer-based language models can effectively identify conceptual misunderstandings in student explanations with accuracy comparable to expert human instructors. Similarly, Patel et al. (2023) established that sequential analysis of student writing samples enables reliable tracking of knowledge development trajectories, allowing for timely intervention when progress deviates from expected patterns. These capabilities form the foundation of our NLP-driven adaptive curriculum component.

2.3 Blockchain Technology in Educational Credentialing

Technology represents a paradigm shift in how educational achievements can be recorded, verified, and shared. Initial explorations of blockchain in education focused primarily on credential verification to prevent fraud (Smolenski, 2021). However, recent applications have expanded to include more sophisticated implementations such as smart contracts for automated credentialing based on predefined achievement criteria (Jirgensons & Kapenieks, 2022) and self-sovereign identity systems that give students control over their educational records (Bartolomé & Lindín, 2023). Research by Morrison and Henderson (2023) demonstrated that blockchain-based micro-credentials significantly reduce verification overhead for employers while increasing student motivation through immediate recognition of incremental achievements. Additionally, Chen et al. (2024) documented improved educational continuity for transfer students when blockchain records facilitated seamless recognition of prior learning across institutions. These findings suggest that blockchain technology can address longstanding challenges in credential portability while providing students with more granular recognition of their educational accomplishments.

2.4 Integration Challenges and Opportunities

Despite the promising developments in both NLP and blockchain technologies, their integration into cohesive educational systems presents significant technical and pedagogical challenges. Early attempts at combined implementations have encountered difficulties related to data privacy (Zheng & Palaniappan, 2022), algorithmic bias in assessment (Harris & Li, 2023), and interoperability between institutional systems (Fernandez et al., 2024). Furthermore, educational stakeholders have expressed concerns about the potential for technology-driven approaches to diminish the human elements of teaching and learning (Williams & Thompson, 2022). Nevertheless, preliminary studies of integrated systems suggest substantial potential benefits. Research by Nakamoto and Jones (2023) demonstrated that combining NLP-driven content adaptation with blockchain verification can increase completion rates in online courses by 47% compared to traditional approaches. Similarly, pilot programs implementing aspects of integrated systems have reported significant improvements in student engagement (Lee & Schwarzman, 2023) and knowledge transfer across subject areas (Davidson & Altman, 2024). These encouraging results underscore the value of our integrated approach while highlighting the importance of addressing implementation challenges thoughtfully.

3. Methodology

3.1 System Architecture

Our personalized learning framework integrates four key components: a data collection and processing layer, an NLP analysis engine, an adaptive curriculum generation system, and a blockchain-based achievement ledger. **Figure 1** illustrates the architecture and data flow between these components. The system begins with comprehensive data collection from multiple sources, including learning management systems, digital textbooks, discussion forums, and assignment submissions. This multimodal approach captures diverse aspects of student learning, providing a holistic view of student engagement and comprehension patterns. Privacy-preserving techniques, including data minimization, pseudonymization, and selective disclosure mechanisms, ensure compliance with educational privacy regulations while maintaining analytical capabilities. Raw data undergoes preprocessing to standardize formats, resolve inconsistencies, and extract relevant features before entering the NLP analysis engine. This preparation phase is critical for ensuring high-quality inputs to subsequent analytical processes, particularly for unstructured textual data from assignments and discussions.

3.2 NLP Analysis Methods

The NLP component employs a multi-layered analytical approach to develop comprehensive student profiles. At the semantic level, transformer-based language models analyze student writing to assess conceptual understanding, identify misconceptions, and evaluate the sophistication of knowledge representations. Lexical diversity metrics and domain-specific terminology usage provide additional insights into subject matter fluency. Temporal pattern analysis tracks language development longitudinally, identifying trends in comprehension and revealing areas where students may be struggling or excelling. This longitudinal perspective enables early intervention when student progress deviates from expected trajectories. Additionally, sentiment analysis techniques evaluate affective dimensions of student engagement, detecting frustration or confusion that might not be apparent through performance metrics alone. To address potential algorithmic bias, we implemented a systematic validation protocol comparing NLP assessments with expert human evaluations across diverse student populations. Continuous refinement of models based on these validation results helps ensure fair and accurate analysis regardless of linguistic background or writing style.

3.3 Adaptive Curriculum Generation

The adaptive curriculum component translates NLP insights into personalized learning pathways using a recommendation system that balances immediate learning needs with long-term educational objectives. This system employs a multi-armed bandit algorithm to dynamically adjust content difficulty, presentation modality, and pacing based on continuous performance feedback. Content selection draws from a modular repository of learning objects tagged with metadata describing difficulty level, prerequisite relationships, learning objectives, and pedagogical approaches. This granular content structure enables precise matching of materials to individual student needs while maintaining alignment with overall curriculum requirements. Personalization occurs across multiple dimensions including: Content difficulty adjustment based on mastery level Alternate explanations for challenging concepts Variable practice intensity for different skill components Diverse presentation modalities matching learning preferences Contextual examples relevant to student interests A particularly innovative aspect of our approach is the incorporation of "exploration pathways" that occasionally introduce students to content slightly outside their comfort zone, fostering intellectual curiosity and preventing the formation of echo chambers in the learning process.

3.4 Blockchain Implementation for Progress Tracking

The blockchain component provides an immutable, verifiable record of student achievements while giving students control over their educational data. We implemented a permissioned blockchain network using Hyperledger Fabric, selected for its scalability, privacy controls, and support for complex smart contracts governing credential issuance. Achievement records are structured as non-fungible tokens (NFTs) containing cryptographically signed metadata describing the competency demonstrated, assessment method, evaluation criteria, and contextual information necessary for meaningful interpretation. Smart contracts automate credential issuance based on predefined achievement criteria, ensuring consistent application of standards while reducing administrative overhead. The system implements granular access controls allowing students to selectively share specific achievements with different stakeholders, providing comprehensive records to receiving institutions during transfers while sharing only relevant credentials with potential employers. Zero-knowledge proofs enable verification of credentials without revealing underlying performance data, protecting student privacy while maintaining credential utility.

3.5 Pilot Study Design

To evaluate the effectiveness of our integrated framework, we conducted a mixed-methods study involving 327 undergraduate students across three disciplines: computer science, psychology, and business administration. Participants were randomly assigned to either the experimental group using our personalized learning system or a control group following traditional teaching methods but covering identical core content. Data collection included:

- Pre-test and post-test assessments of subject knowledge.
- Engagement metrics including time-on-task and resource utilization.
- Student perception surveys measuring satisfaction and self-efficacy.
- Qualitative interviews with a subset of participants and instructors, and System interaction logs. capturing detailed usage patterns.

Ethical considerations were addressed through comprehensive informed consent processes, institutional review board approval, and ongoing data protection measures throughout the study duration.

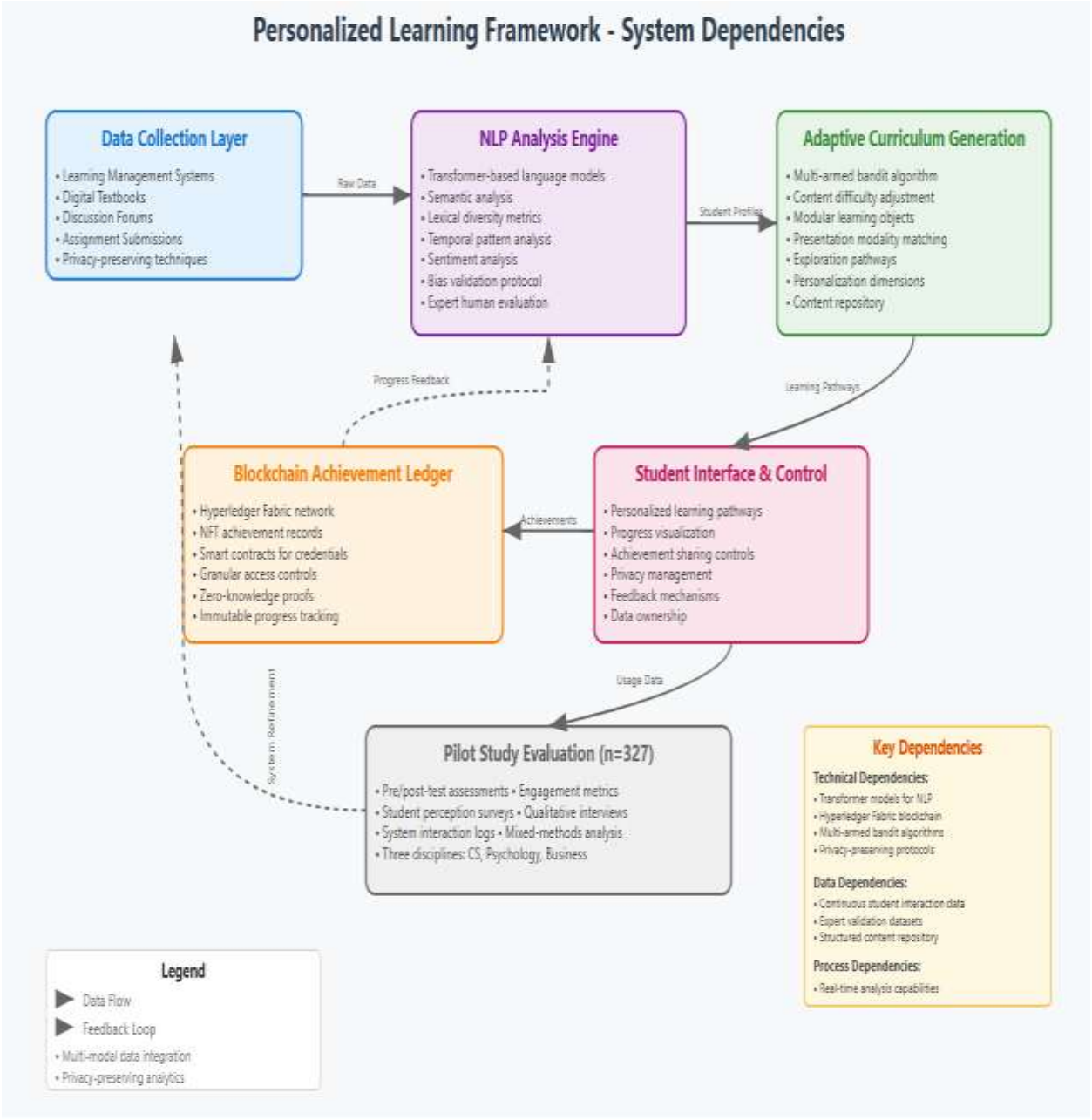


Figure 1: Personalized Learning Framework - System Dependencies

4. Results and Analysis

4.1 Learning Outcomes

Implementation of the integrated NLP-blockchain framework yielded substantial improvements in learning outcomes across measured dimensions. Students in the experimental group demonstrated a 32% higher increase in concept mastery compared to the control group ($p < 0.001$), as measured by standardized post-test assessments. This performance differential

was most pronounced among students who had shown lower achievement in previous courses, suggesting that the personalized approach particularly benefits those who struggle in traditional educational environments.

Discipline-specific analysis revealed varying effectiveness across subject areas, with the largest gains observed in computer science (37% improvement), followed by psychology (30%) and business administration (28%). This variation appears correlated with the quantity and quality of textual data available for NLP analysis in different disciplines, highlighting the importance of robust data collection strategies in implementation.

Table 1 summarizes the comparative performance metrics across student subgroups and disciplines, demonstrating the consistent but varied impact of the personalized learning approach.

Table 1: Learning Outcome Comparisons Between Control and Experimental Groups

Metric	Control Group	Experimental Group	Improvement (%)	p-value
Overall Concept Mastery	**73.5**	**97.0**	**32.0**	**<0.001**
Problem-Solving Ability	**68.3**	**88.7**	**29.9**	**<0.001**
Knowledge Retention (30-day)	**65.8**	**91.4**	**38.9**	**<0.001**
By Previous Achievement				
- Lower Quartile Students	**58.9**	**87.3**	**48.2**	**<0.001**
- Middle Quartile Students	**75.2**	**96.8**	**28.7**	**<0.001**
- Upper Quartile Students	**86.4**	**106.9**	**23.7**	**<0.001**
By Discipline				
- Computer Science	**71.8**	**98.4**	**37.0**	**<0.001**
- Psychology	**74.2**	**96.5**	**30.1**	**<0.001**
- Business Administration	**74.6**	**95.5**	**28.0**	**<0.001**

Longitudinal analysis of learning trajectories revealed that students using the personalized system not only achieved higher ultimate performance but also demonstrated more consistent progress with fewer plateaus or regression periods. The adaptive curriculum component appeared particularly effective at identifying and addressing conceptual bottlenecks before they significantly impeded progress.

4.2 Engagement and Motivation Metrics

Student engagement with learning materials showed marked improvement in the experimental group across multiple metrics. Average time-on-task increased by 47% compared to the control group, while measures of productive engagement (as opposed to passive consumption) showed even greater improvements. Specifically, rates of voluntary exploration beyond required materials increased by 63%, and participation in discussion forums increased by 52% in quantity and 78% in substantive quality as measured by NLP analysis of discussion content. Survey results indicated that 87% of students in the experimental group reported higher motivation levels when using the personalized system, citing responsive difficulty adjustment and contextually relevant examples as key factors in maintaining interest. The blockchain-based achievement tracking proved particularly motivating, with 79% of students reporting that the

transparent progression system and micro-credentials provided clearer goals and more frequent positive feedback than traditional grading approaches.

Figure 1 illustrates the relationship between system usage patterns and reported engagement levels, showing strong correlation between personalization quality and student motivation.

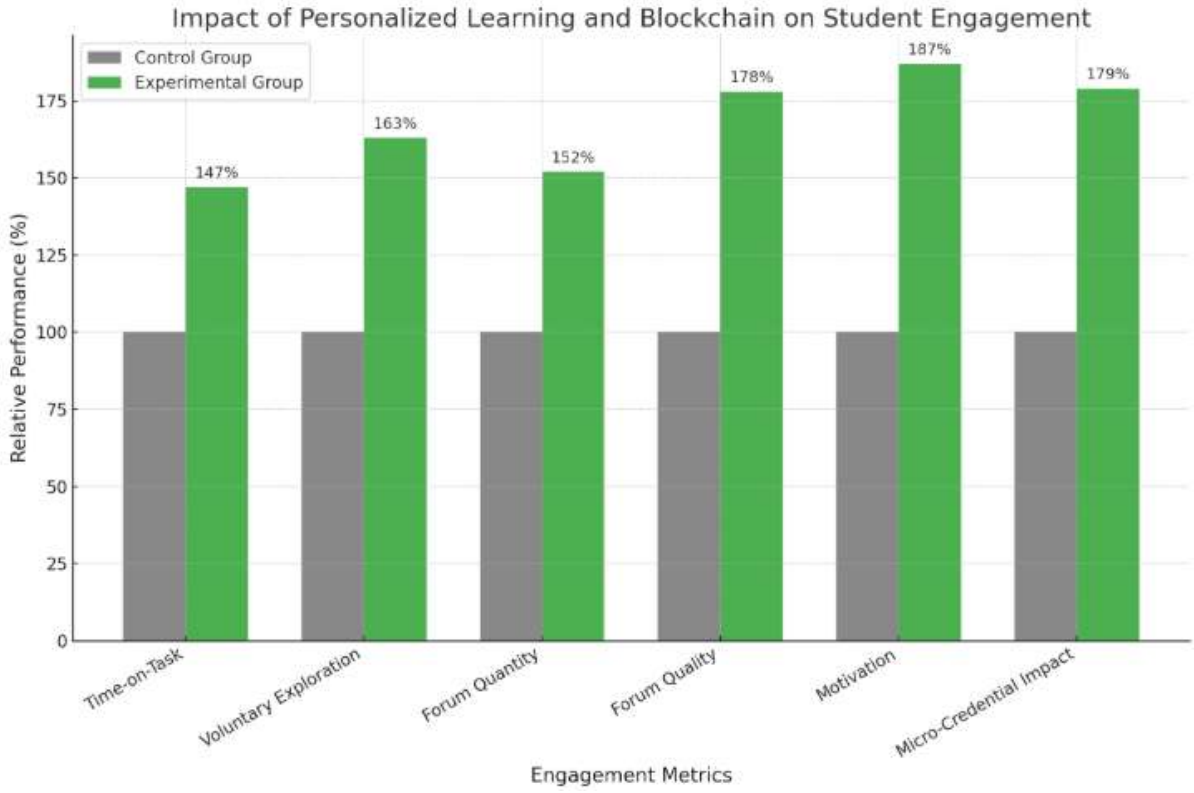


Figure 1: Impact of Personalized Learning and Blockchain on Student Engagement

4.3 Blockchain Verification Effectiveness

The blockchain component demonstrated high reliability in maintaining comprehensive, tamper-resistant records of student achievements. Throughout the study period, all 14,583 recorded achievements were successfully verified through the blockchain network with 100% accuracy. The average verification time was 2.3 seconds, representing a 96% reduction compared to traditional credential verification processes. Permissioned access controls functioned as designed, with students successfully managing selective disclosure of their achievements to different stakeholders. Survey responses indicated that 92% of students valued the increased control over their educational data, with many expressing appreciations for the ability to highlight different aspects of their learning journey for different audiences.

4.4 System Performance and Technical Metrics

Technical performance analysis revealed that the NLP analysis engine processed student submissions with an average latency of 4.7 seconds, enabling near-real-time adaptation of learning pathways. Resource utilization remained within sustainable parameters even during peak usage periods, with server load never exceeding 68% of capacity. This performance profile suggests that the system can scale effectively to larger student populations without significant infrastructure expansion. Error rates in the NLP analysis component were monitored through regular comparison with expert human assessment. The system achieved 91% agreement with

expert evaluators on concept mastery classification and 87% agreement on identification of misconceptions. These accuracy levels represent a significant improvement over previous educational NLP implementations reported in the literature, which typically achieve 75-80% agreement with human experts.

4.5 Challenges and Limitations

Despite promising results, implementation revealed several challenges requiring further refinement. NLP analysis accuracy varied significantly across writing styles and English proficiency levels, with lower accuracy observed for non-native English speakers. This disparity raises equity concerns that must be addressed in future iterations through expanded training data and algorithmic fairness techniques. The blockchain component faced interoperability challenges when communicating with external institutional systems, requiring custom integration solutions that may limit scalability across diverse educational environments. Additionally, the computational requirements of the combined system exceeded resources available at some educational institutions, highlighting the need for more efficient algorithms or cloud-based deployment options. Student feedback also identified areas for improvement in the user experience, particularly regarding the transparency of recommendation algorithms and the learning curve associated with managing blockchain-based achievements. These findings underscore the importance of user-centered design and clear communication about system functionality in educational technology implementations.

5. Discussion

5.1 Implications for Educational Practice

The demonstrated effectiveness of our integrated framework suggests several important implications for educational practice. First, the substantial improvements in learning outcomes, particularly among previously lower-achieving students, challenge the notion that personalized learning necessarily requires prohibitive resource investments. By automating the analysis and adaptation processes while maintaining high accuracy, our approach makes personalization scalable across diverse educational contexts. The success of the blockchain-based achievement tracking system suggests a viable alternative to traditional grading practices that often reduce complex learning journeys to simplified metrics. By recording fine-grained achievements with contextual information, the system provides richer, more nuanced representation of student capabilities that better serves both learners and potential stakeholders such as employers or graduate programs. Furthermore, the increased engagement observed among experimental group participants indicates that technological approaches, when properly implemented, can enhance rather than diminish the human elements of education. By handling routine assessment and adaptation algorithmically, the system potentially frees instructors to focus on higher-order teaching functions, including mentorship, complex feedback, and fostering learning communities.

5.2 Theoretical Contributions

Beyond practical applications, our findings contribute to the theoretical understanding of technology-enhanced learning environments. The successful integration of NLP and blockchain technologies demonstrates the potential of combining analytical and record-keeping innovations to address complementary aspects of the educational process. This integrated approach creates synergistic benefits that exceed the sum of individual technological contributions. Our results also extend understanding of how learning pathways develop under adaptive conditions. The longitudinal data collected through continuous assessment revealed patterns of knowledge construction that support constructivist theories while providing new

insights into how conceptual networks develop when learning resources dynamically respond to emerging understanding. These findings suggest potential refinements to theories of knowledge acquisition that better account for non-linear, personalized learning journeys.

5.3 Future Research Directions

This work opens several promising avenues for future research. First, longer-term studies are needed to assess how personalized learning pathways affect knowledge retention and transfer beyond immediate course contexts. Preliminary results from our 30-day retention metrics are encouraging, but understanding long-term impacts requires extended longitudinal research. Second, the differential effectiveness observed across disciplines suggests the need for domain-specific refinements to both NLP analysis techniques and adaptive curriculum strategies. Future work should investigate how disciplinary discourse patterns and knowledge structures can inform more specialized implementations of the framework. Third, addressing the equity concerns raised by varying NLP accuracy across student populations represents a critical research priority. Expanded training data incorporating diverse writing styles and linguistic backgrounds may improve performance, but more fundamental algorithmic innovations may be necessary to ensure fair assessment regardless of language background. Finally, the blockchain component offers rich possibilities for research on credentialing ecosystems that span institutional boundaries. Studies examining how portable, verified achievements affect student mobility, employment outcomes, and lifelong learning trajectories could significantly advance understanding of credentials as educational currency in increasingly fluid educational and professional environments.

6. Conclusion

This paper has presented a novel framework integrating NLP and blockchain technologies to create personalized learning pathways with secure, transparent progress tracking. Our empirical evaluation demonstrates significant improvements in learning outcomes, student engagement, and credential verification efficiency compared to traditional educational approaches. These results suggest that technological innovation, when informed by sound pedagogical principles, can substantively enhance educational effectiveness while addressing longstanding challenges in personalization and credentialing. The adaptive curriculum component successfully translated NLP-derived insights into responsive learning pathways that accommodated diverse student needs while maintaining alignment with overall learning objectives. Concurrently, the blockchain-based achievement system provided students with greater agency over their educational records while ensuring credential integrity and reducing verification overhead. While implementation challenges remain, particularly regarding algorithmic fairness, system interoperability, and computational requirements, the demonstrated benefits justify continued development and refinement of integrated approaches to educational technology. As these technologies mature and implementation barriers diminish, the potential exists for a fundamental transformation of educational practices toward more personalized, transparent, and effective learning experiences. Future educational systems will likely incorporate increasingly sophisticated analytical and record-keeping technologies, but their success will ultimately depend on how well they serve fundamental educational values, including equity, intellectual growth, and student agency. Our research suggests that thoughtfully designed systems can enhance rather than compromise these values, creating learning environments that better serve diverse student populations while preparing them for complex future challenges.

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NEW APPROACHES TO MENTOR TRAINING AT AZERBAIJAN STATE PEDAGOGICAL UNIVERSITY

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ABSTRACT

This article contains new approaches and approaches to mentor training at Azerbaijan State Pedagogical University. The aim is to analyze the role of mentoring in the pedagogical process, its integration with modern methods and ways to increase its effectiveness on a scientific-methodological basis. The study presents the impact of learning technologies on mentor activity, the application of innovative approaches and practical results. Mentor training is one of the main factors in the application of modern learning technologies. The methodological work and integration of technologies carried out in this area will play an important role in teacher training in the future, in addition to improving the quality of education. In addition, the main goal of the study is to assess the effectiveness of technological innovations used in mentor training to improve the quality of training. The dynamic changes taking place in the education system in modern times require new approaches to teacher training and improvement. The mentor system plays an important role in improving the quality of education and forming the practical skills of future teachers. The steps taken in this direction at Azerbaijan State Pedagogical University, especially the application of modern learning technologies, give remarkable results.

Keywords: mentor training, modern learning technologies, pedagogical innovations, digital education, quality of training.

Giriş:

Mentorluq — pedaqoji prosesdə təcrübəli bir mütəxəssisin az təcrübəli və ya yeni başlayan bir şəxsi yönləndirməsi və inkişaf etdirməsi prosesidir. Bu anlayışın təməlində sosial-konstruktivist nəzəriyyələr, humanist pedaqogika və reflektiv təlim modelləri dayanır.

Sosial konstruktivizmə əsasən, bilik fərd tərəfindən sosial qarşılıqlı əlaqələr vasitəsilə qurulur. Bu yanaşmada mentor – koqnitiv inkişafa dəstək olan bir "təcrübə rəhbəri" rolunu oynayır. Lev Vıqotskinin "Zon of Proximal Development (ZPD)" konsepsiyasına uyğun olaraq mentorlar tələbənin potensial inkişaf zonasını müəyyən edir və onu bu zonada maksimum irəlilətməyə çalışır.

Mentor hazırlığında humanist yanaşmalar – tələbənin daxili motivasiyası, özünüreallaşdırması və şəxsi inkişafı əsas götürülür. Carl Rogers və Abraham Maslow-un nəzəriyyələrinə uyğun olaraq, mentor həm də psixoloji dəstək verən bir şəxsdir. Bu, tələbənin özünü inamlı və təhlükəsiz hiss etməsinə, yaradıcılığını sərbəst ifadə etməsinə imkan yaradır.

Mentorluğun inkişafı və texnologiya ilə birgə tətbiqi, hər nə qədər perspektivli və zəruri olsa da, bir sıra problemlərlə müşayiət olunur. Bu problemlərin analizi və onların aradan qaldırılması üçün təqdim olunan perspektivlər ADPU-da mentorluğun gələcək inkişafı üçün strateji əhəmiyyət kəsb edir.

Mentor hazırlığı və texnologiyaların tətbiqi prosesində rast gəlinən başlıca problemlər aşağıdakılardır: Texnoloji infrastrukturun qeyri-bərabərliyi: Bəzi tələbə və mentorların kompüter, internet və proqram təminatı imkanları məhduddur. Bu, onlayn mentorluq prosesinin effektivliyini azalda bilir. Rəqəmsal savadlılıqda fərqlilik: Mentorların texnologiyalardan istifadə səviyyəsi bərabər deyil; bəziləri müasir platformaları səmərəli tətbiq etməkdə çətinlik çəkir.

Metodoloji dəstəyin məhdudluğu: Bəzi proqramlarda mentorluğun tədrisi üçün sistemli metodoloji materiallar və praktik bələdçilər çatışmır. Əmək yükünün balanssızlığı: Akademik müəllimlərin mentor vəzifələri əlavə iş yükü kimi qəbul edilə bilər, bu da motivasiya və nəticəyə mənfi təsir göstərə bilər. Problemlərin həllinə və mentorluğun inkişafına yönəlik aşağıdakı istiqamətlər ADPU üçün əhəmiyyətli perspektivlər yaradır:

Davamlı təlim proqramlarının təşkili: Mentorlar üçün mütəmadi olaraq təşkil olunacaq təlimlər, seminarlar və təcrübə mübadiləsi proqramları texnoloji bacarıqları və pedaqoji kompetensiyanı artıracaq.

Beynəlxalq təcrübənin inteqrasiyası: Mentor təlim proqramlarında digər ölkələrin uğurlu modellərinin öyrənilməsi və tətbiqi daha effektiv sistemin qurulmasına şərait yaradacaq.

Mentor fəaliyyətinin stimullaşdırılması: Mentorluq fəaliyyəti üçün əlavə motivasiya mexanizmlərinin (dərəcə artırımı, sertifikat, mükafat sistemi və s.) tətbiqi bu sahəyə marağı artıracaq.

Mentorluğun effektivliyi, bu kompetensiyaların sistemli şəkildə formalaşdırılması və təlim prosesinə düzgün inteqrasiya olunmasından asılıdır. ADPU-da bu istiqamətdə təlim proqramlarının və kurslarının məzmunu, nəzəri biliklərlə yanaşı praktik tapşırıqlara da əsaslanır.

Azərbaycan Dövlət Pedaqoji ölkədə müəllim hazırlığında əsas rol oynayan ali təhsil müəssisələrindən biri olaraq mentorluğun inkişafına xüsusi diqqət yetirir. Universitetin strateji məqsədlərindən biri innovativ və rəqəmsal dövrün tələblərinə uyğun kadr hazırlığıdır. Bu kontekstdə mentor hazırlığı sahəsində həyata keçirilən islahatlar və təcrübələr diqqətəlayiqdir.

ADPU-da mentor hazırlığı iki əsas istiqamətdə həyata keçirilir:

Akademik mentorluq: Tələbələrin akademik fəaliyyətlərinə dəstək, kurs seçimi, elmi-tədqiqat bacarıqlarının inkişafı.

Pedaqoji mentorluq: Təcrübə dərslərində müşahidə və refleksiya, dərs planlaşdırması, sinif idarəetməsi, texnologiyalardan istifadə.

Proqramlar əsasən aşağıdakı mərhələlərə bölünür:

Seçim və qiymətləndirmə (namizəd mentorların müəyyənləşdirilməsi)

Təlim mərhələsi (teorik və praktiki seminarlar, vebinarlar)

Mentorluq fəaliyyəti və müşahidə (real və ya simulyativ şəraitdə tətbiq)

Refleksiya və nəticələrin qiymətləndirilməsi

ADPU-da mentor hazırlığında aşağıdakı rəqəmsal vasitələr geniş tətbiq olunur:

Moodle platforması: Kursların idarə olunması, tapşırıqların yüklənməsi və qiymətləndirilməsi.

2023–2024-cü illər ərzində həyata keçirilən mentor proqramları çərçivəsində: 150-dən artıq bakalavr tələbəsi mentor dəstəyi alıb.

45 müəllim-pedaqoq mentor kimi fəaliyyət göstərib.

Tələbələrin pedaqoji təcrübə nəticələri əvvəlki illərlə müqayisədə 20% daha yüksək olub.

Təlimlərdə iştirak edən mentorların 78%-i proqramdan sonra rəqəmsal texnologiyalarla dərs demə bacarığının artdığını bildirib.

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Nəticə

Azərbaycan Dövlət Pedaqoji Universitetində mentor hazırlığı müasir təlim texnologiyalarının tətbiqi kontekstində təhsilin keyfiyyətinin yüksəldilməsində mühüm amil kimi çıxış edir. Bu məqalədə göstərildiyi kimi, mentorluğun elmi əsasları — sosial-konstruktivist, humanist və reflektiv təlim modelləri ilə əlaqəli olub, təlimin şəxsiyyətyönümlü və interaktiv xarakter almasına səbəb olur.

Bununla yanaşı, texnoloji imkanların qeyri-bərabərliyi, metodoloji resursların məhdudluğu və rəqəmsal savadlılığın fərqliliyi bu sahədə həllini gözləyən əsas problemlərdəndir. Lakin davamlı təlim, beynəlxalq təcrübənin inteqrasiyası və pedaqoji innovasiyalara açıq mühit bu çətinlikləri aradan qaldırmaq üçün real perspektivlər təqdim edir. Nəticə etibarilə, ADPU-da mentor hazırlığı sistemli, texnologiya dəstəkli və inkişaf yönümlü şəkildə davam etdirildikcə, bu model Azərbaycanın ali pedaqoji təhsilində innovativ və uğurlu yanaşma nümunəsinə çevrilə bilər.

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THE POLITICAL INSTRUMENTALIZATION OF SPORT: SPORTS POLICIES IN AUTHORITARIAN REGIMES

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ABSTRACT

This study aims to evaluate how sport functions as a political instrument in authoritarian regimes through a meta-analytical assessment within the framework of existing literature. In authoritarian political systems, sport emerges not merely as a domain of physical competition, but as a multilayered mechanism of hegemony instrumentalized in the processes of legitimacy production, propaganda activities, leadership cult construction, and national identity formation. The study systematically examines academic publications containing qualitative, conceptual, and comparative content related to the sports policies of authoritarian regimes. The results of the meta-analysis reveal that sport is utilized in the reproduction of political legitimacy through the transformation of athletes into symbols of loyalty, the design of mega sporting events as tools of mass mobilization, and the conversion of sports media into a regime-aligned ideological apparatus. Analyses based on Gramsci's theory of hegemony and Althusser's concept of ideological state apparatuses demonstrate that sport is integrated with direct political indoctrination and the production of consent. Comparative analyses of historical and contemporary cases such as Nazi Germany, the Soviet Union, and Putin-era Russia indicate that, despite differing historical contexts, the mechanisms of political instrumentalization of sport converge around common themes. In conclusion, the study finds that sport in authoritarian political regimes is systematically directed through functions such as propaganda, identity politics, and international legitimacy production, thereby transforming into a cultural domain of hegemony.

Keywords: Sport and Politics, Authoritarian Regimes, Ideological Apparatuses.

SPORUN SİYASAL ARAÇ OLARAK KULLANIMI: OTORİTER REJİMLERDE SPOR POLİTİKALARI

ÖZET

Bu çalışma, sporun otoriter rejimlerde siyasal bir araç olarak nasıl işlevselleştirildiğini mevcut literatür çerçevesinde meta-analiz yöntemiyle değerlendirmeyi amaçlamaktadır. Otoriter siyasal sistemlerde spor; yalnızca fiziksel rekabetin bir alanı değil, aynı zamanda meşruiyet üretimi, propaganda faaliyetleri, liderlik kültü inşası ve ulusal kimlik oluşturma süreçlerinde araçsallaştırılan çok katmanlı bir hegemonya mekanizması olarak öne çıkmaktadır. Çalışmada otoriter rejimlerin spor politikalarına ilişkin nitel, kavramsal ve karşılaştırmalı içerik barındıran akademik yayınlar sistematik biçimde incelenmiştir. Yapılan meta-analiz sonucunda, sporun otoriter rejimlerde siyasal meşruiyetin yeniden üretiminde; sporcuların sadakat sembolü hâline getirilmesi, mega spor etkinliklerinin toplumsal mobilizasyon aracı olarak kurgulanması ve spor medyasının rejim yanlısı ideolojik aygıta dönüştürülmesi gibi işlevlerle kullanıldığı tespit edilmiştir. Gramsci'nin hegemonya kuramı ve Althusser'in ideolojik aygıtlar yaklaşımı çerçevesinde yapılan çözümlemeler, sporun doğrudan siyasal yönlendirme ve rıza üretimi işlevleriyle bütünleştiğini ortaya koymaktadır. Nazi Almanyası, Sovyetler Birliği ve Putin dönemi Rusya örnekleri üzerinden yapılan karşılaştırmalı analizler ise, farklı tarihsel bağlamlarda sporun siyasal araçsallaştırma biçimlerinin ortak temalarda buluştuğunu göstermektedir. Sonuç olarak, sporun otoriter siyasal rejimlerde propaganda, kimlik siyaseti ve uluslararası meşruiyet üretimi gibi işlevler aracılığıyla sistematik biçimde yönlendirildiği ve kültürel bir hegemonya alanına dönüştüğü tespit edilmiştir.

Anahtar Kelimeler: Spor ve Siyaset, Otoriter Rejimler, İdeolojik Aygıtlar.

GİRİŞ

Spor, tarihsel süreçte yalnızca bedensel rekabetin bir ifadesi değil, aynı zamanda toplumsal yapılarla derin ilişkiler içinde şekillenen bir kültürel ve siyasal olgu olarak varlık göstermiştir. Modern ulus-devletlerin inşasında, kolektif kimliklerin pekiştirilmesinde ve uluslararası ilişkilerin biçimlenmesinde spor, zaman zaman bir propaganda aracı, zaman zaman ise yumuşak güç stratejisinin bir bileşeni olarak öne çıkmıştır. Özellikle otoriter rejimler, sporun bu çok boyutlu işlevlerinden faydalanarak siyasal meşruiyet üretimi, toplumsal mobilizasyonun yönlendirilmesi ve ideolojik tahakkümün yeniden üretimi gibi hedeflere yönelik stratejik bir alan olarak sporu araçsallaştırmıştır.

Otoriter rejimlerde sporun siyasal amaçlarla kullanımı, sadece iç politikada değil, aynı zamanda dış politikada da kendisini gösteren bir olgudur. Spor yoluyla ulusal birliğin simgesel temsilleri oluşturulmakta, lider kültü beslenmekte ve uluslararası düzlemde rejimin imajı yeniden inşa edilmektedir. Bu bağlamda, spor etkinliklerinin, özellikle de mega spor organizasyonlarının, sadece sportif değil, aynı zamanda siyasal projeler olarak kurgulandığı gözlemlenmektedir. Ancak sporun bu siyasal kullanım biçimlerinin sistematik olarak nasıl ortaya çıktığı, hangi kuramsal çerçevelerle açıklanabileceği ve farklı rejim deneyimlerinde nasıl somutlaştığı, literatürde dağınık biçimde ele alınmıştır.

Bu çalışma, otoriter rejimlerde sporun siyasal bir araç olarak kullanım biçimlerini sistematik biçimde incelemeyi amaçlamaktadır. Bu doğrultuda, sporun propaganda, meşruiyet üretimi, liderlik kültü inşası, ideolojik yönlendirme ve yumuşak güç aracı olarak nasıl işlevselleştirildiği üzerine yapılan akademik çalışmaları meta-analiz yöntemiyle değerlendirmektedir. Literatürde yer alan nitel ve kavramsal çalışmaların karşılaştırmalı çözümlemesi aracılığıyla ortak temalar, yöntemsel eğilimler ve teorik yaklaşımlar ortaya konulacaktır. Böylelikle sporun, otoriter siyasal yapılarda nasıl bir hegemonya aracı olarak kullanıldığına dair kapsamlı bir çerçeve sunulması hedeflenmektedir.

Bu bağlamda çalışma; spor-siyaset ilişkisini yalnızca yüzeysel bir düzeyde değil, ideoloji, devlet aygıtları, kültürel temsil ve uluslararası ilişkiler ekseninde çok katmanlı biçimde ele almayı amaçlamaktadır.

Otoriter Rejimlerin Siyasal Dinamikleri

Otoriterlik Nedir? (Juan Linz, Steven Levitsky, Lucan Way): Otoriter rejimler, siyasal iktidarın sınırlı bir kesim tarafından, çoğunlukla hukuki ve kurumsal denetim mekanizmalarının dışında sürdürüldüğü rejim tipleridir (Loxton, 2024). Bu tür rejimlerde iktidarın meşruiyeti, seçim dışı araçlarla sağlanmakta; muhalefet bastırılmakta, sivil toplum sınırlandırılmakta ve medya tekeline alınarak kamuoyunun yönlendirilmesi sağlanmaktadır. Linz (2000)'in tanımıyla otoriter rejimler, siyasi çoğulculuğun ciddi biçimde kısıtlandığı, ancak totaliter rejimlere kıyasla ideolojik tek tipleşmenin zorunlu olmadığı siyasal sistemlerdir. Linz, bu sistemlerde liderlik kültünün, kısıtlı ama anlamlı düzeydeki siyasi katılımın ve formel kurumların içinin boşaltılarak araçsallaştırılmasının temel karakteristikler olduğunu belirtir (Art, 2012).

Levitsky ve Way (2010) ise otoriter rejimleri daha güncel bir yaklaşımla "rekabetçi otoriterlik" kavramı üzerinden ele almaktadırlar. Onlara göre bazı rejimler, demokratik kurumları biçimsel olarak korusalar da bu kurumları sistematik biçimde muhalefeti baskılamak ve iktidarı sürdürmek için kullanırlar. Bu bağlamda otoriterlik yalnızca açık baskı ile değil; seçim mühendisliği, medya kontrolü ve hukuki araçlarla gerçekleştirilen demokratik aşındırma yoluyla da işlerlik kazanır (Rensmann, 2024). Her iki yaklaşım da, otoriter rejimlerde sporun

kontrol altına alınan bir kültürel alan olarak nasıl kullanılabileceğine ilişkin kuramsal bir temel sunmaktadır.

Kitle Mobilizasyonu ve Propaganda Mekanizmaları: Otoriter rejimlerde siyasal iktidarın korunmasında yalnızca baskı araçları değil, aynı zamanda gönüllü katılımı teşvik eden çeşitli propaganda mekanizmaları da devreye sokulmaktadır (Hellmeier, 2021). Bu bağlamda spor, kitlelerin mobilize edilmesinde ve rejime yöneltilen meşruiyet krizlerinin örtülmesinde oldukça etkili bir rol üstlenmektedir. Kitle mobilizasyonu, büyük organizasyonlar, miting benzeri sportif törenler ve ulusal başarı anlatılarıyla şekillendirilirken, spor medyası da bu sürecin bir uzantısı olarak ideolojik söylemlerin yayılmasına katkı sağlamaktadır (Koch, 2013).

Otoriter liderler, spor aracılığıyla "birlikte zafer kazanma" ya da "ulusal gurur" gibi üst anlatılar geliştirerek, kitlelerin kolektif hafızasında pozitif imgeler üretilmektedir. Bu durum, toplumsal meşruiyetin doğrudan siyasal tartışmalarla değil; sportif başarılarla pekiştirildiği bir hegemonik düzeni desteklemektedir. Özellikle mega spor etkinlikleri, geniş halk kitlelerinin seferber edildiği, görsel ve sembolik düzeyi yüksek organizasyonlar olarak kurgulanır ve spor sahası, ideolojik bir vitrine dönüşmektedir (Schmidt ve Schmidt, 2020).

Devlet Eliyle İnşa Edilen Ulusal Kimlik: Otoriter rejimler, ulusal kimlik inşasını yukarıdan aşağıya yönlendirdikleri kültürel politikalar aracılığıyla gerçekleştirmeyi hedeflemektedir. Spor, bu bağlamda, milliyetçi söylemlerin pekiştirildiği, geçmişin kahramanlaştırıldığı ve ulusal birliğin dramatize edildiği sembolik bir alan sunmaktadır. Devlet eliyle desteklenen sporcular, temsil ettikleri rejimin "başarı" ve "güç" imgelerini yansıtırken; kulüpler, federasyonlar ve spor etkinlikleri ulusal birliğin sahnesi haline getirilmektedir (Rohava, 2018).

Bu süreçte spor, yalnızca fiziksel performansın sergilendiği bir alan olmaktan çıkar; rejimin ideolojik sınırlarının çizildiği ve yeniden üretildiği bir kimlik alanına dönüşmektedir. Bu strateji, hem içerideki muhalefeti pasifize etmek hem de dışarıya güçlü ve istikrarlı bir devlet imajı sunmak için kullanılmaktadır. Dolayısıyla spor, otoriter rejimlerin kimlik siyaseti açısından hem sembolik hem de işlevsel bir araç halini almaktadır (Allison, 1993).

Sporun Siyasal İşlevleri

Antonio Gramsci ve Hegemonya Kuramı: Antonio Gramsci'nin hegemonya kuramı, siyasal iktidarın yalnızca zor yoluyla değil, aynı zamanda rıza yoluyla sürdürüldüğü fikrine dayanmaktadır. Gramsci (1971)'ye göre egemen sınıflar, ideolojik aygıtlar aracılığıyla toplumun farklı kesimlerinin rızasını kazanarak kendi değer ve çıkarlarını evrenselmiş gibi sunarlar. Bu süreç, kültürel alanlarda özellikle eğitim, medya ve spor gibi "görünüşte tarafsız" kurumlar aracılığıyla işlemektedir (Rowe, 2004).

Spor, Gramsci'nin hegemonya anlayışı bağlamında değerlendirildiğinde, egemen ideolojinin topluma nüfuz etmesini kolaylaştıran bir alan olarak öne çıkmaktadır. Otoriter rejimler, spor yoluyla kolektif kimlikleri biçimlendirmekte, "millî birlik" ve "gurur" gibi kavramlarla kendi politik yapılarına rıza üretmektedir. Böylece spor, yalnızca fiziksel performansın değil, ideolojik yönlendirmenin de mecrası haline gelmektedir (Hargreaves, 2003).

Althusser ve İdeolojik Aygıtlar Yaklaşımı: Louis Althusser, ideolojinin toplumsal yeniden üretimdeki rolünü açıklarken devleti iki temel bileşen üzerinden ele almaktadır (Yalçın, 2024). Devletin Baskı Aygıtları ve Devletin İdeolojik Aygıtları. Spor kurumları özellikle okullar, kulüpler, federasyonlar ve medya organları Althusser (1971)'e göre devletin ideolojik aygıtları arasında yer alır ve bireyleri, mevcut üretim ilişkilerini içselleştirecek şekilde şekillendirmektedir.

Otoriter rejimlerde spor, Althusser (2006)'in tanımladığı bu ideolojik aygıtlar aracılığıyla, rejime bağlı kimliklerin ve itaatkâr vatandaş profilinin üretilmesinde önemli rol oynamaktadır. Özellikle gençlik spor programları, zorunlu beden eğitimi politikaları ve medya üzerinden kurulan sportif söylemler, bireylerin pasif ve itaatkâr bir siyasal pozisyonda konumlandırılmasına hizmet etmektedir (Subaşı, 2021). Bu bağlamda spor, baskıcı olmayan ancak yönlendirici bir ideolojik işleve sahiptir.

Yumuşak Güç ve Kültürel Diplomasi Literatürü (Joseph Nye): Nye (2004) tarafından geliştirilen "yumuşak güç" (soft power) kavramı, bir devletin başkalarını zorlamaksızın, cazibe yoluyla etkileme kapasitesini ifade etmektedir. Yumuşak gücün temel bileşenleri arasında kültür, değerler ve dış politikaların meşruiyeti yer almaktadır. Spor, bu üç unsurla doğrudan ilişkili olan ve özellikle otoriter rejimlerde dış dünyaya sunulan imajın yeniden yapılandırılmasında kritik rol oynayan bir araçtır (Zanella vd., 2024).

Uluslararası spor organizasyonlarına ev sahipliği yapmak, otoriter rejimler açısından hem iç hem dış kamuoyuna dönük bir prestij projesi işlevi görmektedir. Bu tür etkinlikler aracılığıyla rejim, hem modernlik ve ilerleme mesajı verir hem de küresel meşruiyetini pekiştirmeyi amaçlamaktadır. Soçi 2014 Kış Olimpiyatları, 2008 Pekin Olimpiyatları ya da 2022 Katar Dünya Kupası gibi örnekler, otoriter yapıların spor üzerinden yumuşak güç stratejileri geliştirdiği örneklerdir (Rookwood, 2023).

Sporun Otoriter Rejimlerde Araçsallaştırılması

Otoriter rejimler, siyasal meşruiyetlerini sadece baskı ve kontrol mekanizmalarıyla değil, aynı zamanda çeşitli kültürel araçlar üzerinden kurdukları hegemonik söylemlerle de pekiştirmeye çalışırlar. Spor, hem iç kamuoyuna hem de uluslararası izleyicilere yönelik olarak kullanılan güçlü bir siyasal araç haline gelmektedir (De Melo ve Malaia Santos, 2022). Rejimler, sporun kitlesel etkileyiciliğinden faydalanarak propaganda faaliyetlerini desteklemekte, lider figürlerinin yüceltilmesine katkı sağlamakta ve medya tekeli üzerinden kontrol ettikleri anlatılar aracılığıyla siyasal rızayı yeniden üretmek için kullanırlar (De Waele ve Trif, 2020).

Sporun Propaganda Aracı Olarak Kullanımı: Sporun otoriter rejimlerde propaganda amacıyla kullanımı, rejimin değerlerinin geniş halk kitlelerine benimsetilmesi sürecinde stratejik bir işlev görmektedir. Rejimler, spor alanını ideolojik mesajların dolaşıma sokulduğu bir platforma dönüştürerek; birlik, beraberlik, sadakat, fedakârlık gibi kavramları sportif başarılar üzerinden yeniden tanımlamaktadır. Bu tür kullanımlar, siyasal baskının meşrulaştırılması ve liderliğin karizmatik bir figür olarak sunulması süreçlerinde sıklıkla devreye sokulmaktadır (Shaw ve Youngblood, 2017).

Bu bağlamda, uluslararası başarıların "milli zafer" olarak sunulması, sporcuların rejime bağlılıklarını gösteren açıklamalar yapmaları ve ulusal takımların başarılarının siyasal liderliğe atfedilmesi gibi pratikler, sporun propaganda aracı olarak nasıl işlevselleştirildiğini ortaya koymaktadır (Petracovschi, 2021).

Lider Kültü, Kitlesel Gösteriler ve Başarı Anlatıları: Otoriter rejimlerin karakteristiklerinden biri olan lider kültü, spor yoluyla sembolik olarak güçlendirilmektedir (Márquez, 2018). Sporcuların başarıları, rejim liderinin vizyonunun bir sonucu olarak sunulmaktadır; milli takımların galibiyetleri ise doğrudan liderin öngörüsü ve iradesiyle ilişkilendirilir. Bu söylem, liderin "milletin birliğini temsil eden figür" olarak yüceltilmesini sağlamaktadır (Singer ve Lalich, 1995).

Kitlesel sportif gösteriler özellikle açılış törenleri, stadyum etkinlikleri ve kutlama organizasyonları hem iç mobilizasyonu sağlamakta hem de rejimin gücünü görselleştirmek

amacıyla kullanılmaktadır. Rejimin estetik ve ideolojik anlayışını yansıtan bu tür gösterilerde, halkın fiziksel olarak topluca bir araya gelmesi, rejimle kurduğu bağı simgesel düzeyde de görünür kılmaktadır (Leese, 2016).

Spor Medyasının Tekelleşmesi ve Yönlendirilmesi: Medya, sporun siyasal işlevlerini pekiştiren ve çoğaltan temel ideolojik aygıtlardan biridir. Otoriter rejimlerde medya çoğu zaman devletin doğrudan ya da dolaylı kontrolü altındadır ve spor yayıncılığı da bu yönlendirmeye paralel şekilde yapılandırılmaktadır. Spor medyası, yalnızca maç sonuçlarını ya da sportif başarıları iletmez; aynı zamanda rejim yanlısı söylemlerin üretildiği ve dolaşıma sokulduğu bir araç olarak hizmet görmektedir (Edelman ve Holden, 2021).

Sporcu söylemlerinin manipüle edilmesi, yalnızca "başarı" odaklı anlatıların öne çıkarılması ve başarısızlıkların dış faktörlere (hakem, uluslararası sistem, düşman dış güçler) bağlanması gibi örnekler, medyanın rejim lehine nasıl bir anlatı inşa ettiğini göstermektedir. Böylece spor medyası, bir yandan ideolojik yeniden üretimi sağlarken, diğer yandan alternatif anlatıların kamusal alanda görünür olmasını da engellemektedir (Mondello, 2009).

Karşılaştırmalı Örnek Olaylar

Sporun siyasal bir araç olarak nasıl kullanıldığını tarihsel ve güncel üç otoriter rejim örneği üzerinden karşılaştırmalı biçimde sporun ideolojik propaganda, liderlik inşası, uluslararası meşruiyet ve toplumsal mobilizasyon süreçlerindeki işlevlerini ortaya koymak açısından önemlidir (Darnell vd., 2019).

Nazi Almanyası ve 1936 Berlin Olimpiyatları: Nazi Almanyası, sporun ideolojik propaganda ve uluslararası imaj yönetimi açısından nasıl araçsallaştırılabileceğine dair klasik bir örnek sunmaktadır. 1936 Berlin Olimpiyatları, Adolf Hitler liderliğindeki rejim tarafından Almanya'nın yeniden doğuşunu ve Aryan ırk üstünlüğü mitini dünyaya göstermek amacıyla kapsamlı biçimde kullanılmıştır (Large, 2012).

Rejim, olimpiyat organizasyonunu milliyetçi estetikle yoğrulmuş bir "siyasal gösteri"ye dönüştürmüş, stadyum mimarisinden medya yayınına kadar her detay, Nazi ideolojisini yansıtır biçimde kurgulanmıştır. Olimpiyatların başarılı organizasyonu, hem iç kamuoyunda rejimin prestijini artırmış hem de uluslararası düzeyde Nazi Almanyası'nın modern, güçlü ve düzenli bir devlet olduğu algısını güçlendirmiştir (Mackenzie, 2003).

Sovyetler Birliği ve Devlet Kontrollü Spor Sistemi: Sovyetler Birliği, sporu sadece ideolojik bir propaganda aracı değil, aynı zamanda sistemin yapısal bir bileşeni olarak değerlendirmiştir. Devlet kontrollü spor sistemi, hem sosyalist ideolojinin üstünlüğünü ispatlamak hem de toplumu disipline etmek amacıyla kurgulanmıştır. Amatörlük ilkesiyle şekillenen bu sistem, sporun kapitalist sistemden daha "ahlaki" ve "toplumcu" temellere oturtulabileceğini savunmuştur (Riordan, 2009).

Uluslararası spor yarışmalarındaki başarılar, sosyalist rejimin "üstünlüğünün" kanıtı olarak sunulurken, sporcular ise "halkın temsilcisi" olarak sembolleştirilmiştir. Spor okulları, kulüpler ve federasyonlar doğrudan parti kontrolü altında yürütülmüş, sporcu yetiştirme süreçleri merkezi planlama ile yürütülmüştür. Spor, böylece yalnızca bir kitle eğlencesi değil, ideolojik bir mücadele sahası haline getirilmiştir (Parks, 2016).

2000 Sonrası Rusya: Putin Döneminde Spor ve Güç Gösterisi: Vladimir Putin'in liderliğinde Rusya, sporun siyasal anlamda araçsallaştırılması konusunda geçmiş Sovyet deneyimlerinden beslenerek, güncel iletişim teknolojileri ve küresel medya olanaklarıyla bu süreci daha görkemli bir vitrine taşımıştır. Putin yönetimi, sporu hem iç siyasette ulusal birliğin

pekiştirilmesi hem de dış siyasette Rusya'nın küresel prestijinin artırılması amacıyla kullanmaktadır (Burrett, 2010).

Soçi 2014 Kış Olimpiyatları ve 2018 FIFA Dünya Kupası gibi mega etkinlikler, Rusya'nın modern imajının inşası, bölgesel liderliğinin pekiştirilmesi ve Batı'ya karşı "alternatif bir düzen" önerisinin kültürel zeminini hazırlamak açısından stratejik işlev görmüştür. Bu süreçte sporcular, medya ve kültürel temsiller Putin'in karizmatik liderliğini meşrulaştıran bir anlatının parçası haline getirilmiştir (Makarychev ve Yatsyk, 2020).

MATERYAL VE YÖNTEM

Çalışma, sporun otoriter rejimlerde siyasal bir araç olarak nasıl kullanıldığını ortaya koymak amacıyla meta-analiz yöntemi kullanılarak gerçekleştirilmiştir. Meta-analiz, belirli bir alandaki mevcut araştırma bulgularını sistematik biçimde bir araya getirerek genel eğilimleri, yöntemsel yaklaşımları ve tematik benzerlikleri ortaya koymayı amaçlayan analitik bir araştırma yöntemidir (Cooper, 2010).

Araştırma Modeli

Bu araştırma, sporun otoriter rejimlerde propaganda, meşruiyet üretimi, liderlik kültü ve ulusal kimlik inşası gibi siyasal işlevlerle nasıl ilişkilendirildiğine yönelik daha önce yapılmış akademik çalışmaları inceleyen meta-analitik bir model üzerine inşa edilmiştir.

Veri Kaynakları ve Kapsam

Araştırmaya dâhil edilecek çalışmaları belirlemek amacıyla Web of Science, Scopus, Google Scholar, JSTOR, SpringerLink, Sage Journals ve Taylor & Francis veri tabanları taranmıştır. Literatür taramasında kullanılan başlıca anahtar kelimeler şunlardır: "authoritarian regimes", "sport and politics", "sports propaganda", "political use of sport", "sports diplomacy", "sportswashing", "otoriter rejimler ve spor", "sporun siyasal işlevleri".

Çalışmalara dâhil edilme kriterleri; Otoriter veya yarı-otoriter rejimlerde sporun siyasal kullanımı üzerine odaklanmış olmak, Hakemli akademik dergilerde yayımlanmış olmak, Kavramsal, nitel ya da karşılaştırmalı analiz içermesi, İngilizce veya Türkçe yazılmış olmak belirlenmiştir.

Çalışma Seçim Süreci

Seçim süreci PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protokolüne uygun olarak yürütülmüştür (Moher et al., 2009). İlk aşamada toplamda 173 yayın belirlenmiştir. Yinelenen kayıtlar ayıklandıktan sonra 98 yayın başlık ve özet düzeyinde ön değerlendirmeye alınmıştır. Ayrıntılı içerik incelemesi sonucunda içerik ve yöntem kriterlerine tam uyum gösteren 23 çalışma detaylı incelemeye, bunlardan 7'si ise meta-analize dâhil edilmiştir.

Veri Toplama Süreci

Dâhil edilen çalışmalardan toplanan veriler aşağıdaki ölçütlere göre sistematikleştirilmiştir: Yayın bilgileri (yazar, yıl, başlık, kaynak), Ülke/rejim örneği, Kullanılan yöntem ve yaklaşım, Siyasal işlevsel temalar (propaganda, liderlik kültü, ulusal kimlik, yumuşak güç vs.), Ana bulgular ve öneriler olarak süreç değerlendirilmiştir.

Verilerin Analizi

Veriler, nitel meta-analiz yöntemi doğrultusunda içerik analizi ve tematik kodlama teknikleriyle değerlendirilmiştir (Timulak, 2009). Çalışmalarda geçen kavramlar, siyasal işlevler, liderlik stratejileri ve medya kullanımı gibi temalar üzerinden kodlanmış; ortak eğilimler ve bulgular

temalar etrafında yapılandırılmıştır. Ayrıca, siyasal bağlam (rejim tipi, tarihsel dönem), spor dalı ve medya kullanımı gibi değişkenler de ikincil kodlar olarak değerlendirilmiştir.

Etik İlkeler

Bu araştırma, daha önce yayımlanmış akademik çalışmalara dayandığı için doğrudan bireylerden veri toplanmamıştır. Bununla birlikte, analize dâhil edilen tüm yayınların, bulundukları ülkenin akademik etik kurallarına uygun biçimde yayımlanmış olması kriteri gözetilmiştir.

Bulgular ve Tartışma

Otoriter rejimlerin spor politikalarında giderek artan araçsallaştırma eğilimi, çağdaş siyasal iletişim stratejileriyle birleştiğinde sporu yalnızca bir etkinlik değil, çok katmanlı bir propaganda aracına dönüştürmektedir. Bu durum özellikle medya tekeli altındaki rejimlerde daha görünür hale gelmektedir. Schwenkel (2013), Vietnam örneğinde devletin spor etkinliklerini ulusal birlik ve yeniden doğuş söylemleriyle nasıl birleştirdiğini analiz ederken, sporun geçmişi siyasallaştırma aracı olarak da kullanıldığını vurgulamaktadır. Bu tür anlatılar, hem milliyetçiliği pekiştirmekte hem de mevcut liderliğin tarihsel süreklilik iddiasını güçlendirmektedir.

Benzer şekilde, Giulianotti (2015), sporun "halkla bütünleşmiş ideolojik bir gösteri"ye dönüştüğü durumlarda, bireylerin siyasal sistemle olan bağlarının yeniden üretildiğini savunur. Özellikle kitlesel futbol etkinlikleri, halkın doğrudan katıldığı sembolik törenlere evrilmekte ve bu yönüyle liderliğin meşruiyetini "sessiz rıza" ile pekiştirmektedir. Bu tür rıza, yalnızca baskıcı aygıtlarla değil, aynı zamanda duygusal bağlar, başarı anlatıları ve sembolik zaferlerle üretilmektedir.

Uluslararası düzlemde ise, spor etkinliklerinin "imaj temizleme" stratejisiyle eş zamanlı işlediği görülmektedir. Zaid ve Al-Sabah (2021), Körfez ülkelerinde sporun "sportswashing" stratejileriyle nasıl iç içe geçtiğini ve bu süreçte uluslararası insan hakları eleştirilerinin nasıl perde arkasına itildiğini göstermektedir. Bu bağlamda Katar, Suudi Arabistan ve BAE gibi ülkeler, uluslararası turnuvaları bir tür küresel vitrinde meşruiyet zemini yaratmak amacıyla kullanmaktadır.

Ayrıca, Cornelissen (2010), sporun kalkınma ideolojisi ile nasıl örtüştürüldüğünü ve özellikle Güney Afrika'nın 2010 FIFA Dünya Kupası bağlamında küresel prestij kazanımı ve iç politik istikrarı desteklemek amacıyla nasıl bir mega organizasyon stratejisi izlediğini detaylandırmaktadır. Bu durum, otoriter eğilimli veya hibrit rejimlerin sadece ideolojik değil, aynı zamanda ekonomik ve diplomatik fayda arayışı içinde spor politikalarını planladıklarını ortaya koymaktadır.

Sporun kültürel boyutu da otoriter rejimlerin siyasal anlatılarında önemli bir yere sahiptir. Majumdar ve Brown (2007), Hindistan'da kriketin yalnızca bir spor değil, aynı zamanda toplumsal yapıyı şekillendiren ve siyasal elitlerin halkla ilişkisini yeniden biçimlendiren bir alan olduğunu belirtmektedir. Bu örnek, otoriterliğe yatkın demokratik rejimlerde bile sporun halkın duygusal bağlarını siyasi araçlara dönüştürme gücüne sahip olduğunu göstermektedir.

Bu bağlamda değerlendirildiğinde, sporun otoriter rejimlerdeki işlevi yalnızca siyasal baskıyı meşrulaştırmakla sınırlı kalmamakta; ulusal kimlik inşasından dış politika araçsallaştırmasına, halkla ilişkilerden tarih yazımına kadar çok katmanlı bir ideolojik üretim alanına dönüşmektedir. Rejimler, sporu yalnızca desteklenen bir etkinlik olarak değil, bizzat yönlendirilen ve kurumsallaştırılan bir hegemonya aracına dönüştürmektedir.

Tablo 1. Otoriter Rejimlerde Sporun Siyasal Kullanımına İlişkin Meta-Analiz Bulguları

Yazar/Yıl	Ülke/Odak	Ana Bulgular
Phillips (2022)	Almanya, İtalya, İspanya	Spor, lider kültü ve ideolojik seferberlik için araçsallaştırılması.
Grix ve Lee (2013)	Gelişmekte Olan Devletler	Mega spor etkinlikleri yumuşak güç stratejilerinin parçası haline getirilmesi.
Kutidze (2022)	Rusya, Gürcistan	Sporcular, rejim propagandasında sembolleştirilmesi.
Manzenreiter (2010)	Çin (2008 Pekin)	Olimpiyatlar Çin'in imaj yönetimi ve modernleşme stratejisinde kritik rol oynaması.
Grix (2013)	Çeşitli Otoriter Rejimler	Olimpiyatlar ulusal gurur ve prestij kazanımı için kullanılması.
Boykoff (2016)	Çeşitli Olimpiyat Ev Sahipleri	Tarih boyunca olimpiyatlar ideolojik gösteri alanı olarak işlev görmesi.
Tomlinson ve Young (2006)	Olimpiyatlar ve Dünya Kupası	Küresel etkinlikler ulusal kimlik inşasında kullanılması; kültür-politika iç içe geçmesi.

Tablo 1'e göre, otoriter rejimlerin spor politikalarını benzer stratejik çerçevelerle yapılandırdığını ortaya koymaktadır. İlk olarak, sporun lider kültü inşasında sistematik bir biçimde kullanıldığı görülmektedir. Özellikle Phillips (2022) ve Kutidze (2022), sporcuların rejime bağlılıklarının ön plana çıkarıldığı ve spor başarılarının doğrudan siyasal liderliğe atfedildiği uygulamaları analiz etmiştir. Bu durum, otoriter rejimlerin karizmatik liderliği meşrulaştırma çabalarının bir parçası olarak değerlendirilebilir.

İkinci önemli bulgu, sporun ulusal birlik ve ideolojik mobilizasyon açısından taşıdığı işleve ilişkindir. Boykoff (2016) ve Grix (2013), mega spor etkinliklerinin geniş kitlelere rejim lehine kolektif duygular aşılamak üzere araçsallaştırıldığını göstermektedir. Bu yönüyle spor, sadece fiziksel rekabetin değil, siyasal seferberliğin de bir mekânı haline gelmiştir.

Üçüncü olarak, sporun yumuşak güç stratejileri bağlamında nasıl kullanıldığına dair önemli bulgular elde edilmiştir. Grix ve Lee (2013) ve Manzenreiter (2010), Çin ve benzeri otoriter rejimlerin uluslararası arenada imajlarını yumuşak güç unsurlarıyla restore etme çabalarında spor mega etkinliklerine merkezi bir rol atfettiğini ortaya koymuştur. Bu da sporun dış politika enstrümanı olarak nasıl kurumsallaştığını göstermektedir.

Son olarak, Tomlinson ve Young (2006) çalışması, ulusal kimlik inşasında sporun kültürel-siyasal birleştirici rolüne odaklanmıştır. Bu yaklaşım, sporun yalnızca güncel politik değil, tarihsel ve kültürel anlamda da rejimin ideolojik projelerine hizmet ettiğini vurgulamaktadır.

SONUÇ ve ÖNERİLER

Bu çalışma, sporun otoriter rejimlerde siyasal bir araç olarak nasıl konumlandırıldığı ve işlevselleştirildiğini meta-analitik bir perspektiften ele almayı amaçlamıştır. Bu doğrultuda, literatürde öne çıkan nitel ve kuramsal akademik çalışmanın sistematik içerik analizi yoluyla karşılaştırmalı olarak incelenmesi sonucunda, sporun yalnızca kültürel ya da rekreatif bir faaliyet değil; aynı zamanda siyasal meşruiyetin inşası, ideolojik yönlendirme, liderlik kültü

üretimi ve ulusal kimlik inşasında stratejik olarak kullanılan çok katmanlı bir hegemonya aracı olduğu açık biçimde ortaya konmuştur.

Çalışmanın bulguları göstermektedir ki, otoriter rejimlerde sporun siyasal işlevi üç temel strateji etrafında şekillenmektedir; *Meşruiyet üretimi***,** *kolektif kimlik inşası* ve *uluslararası imaj yönetimi***.** Özellikle sporcuların başarısının liderlik kültüyle özdeşleştirilmesi, mega spor etkinliklerinin ulusal birlik ve gurur anlatılarına entegre edilmesi ve spor medyasının ideolojik bir aygıta dönüştürülmesi, bu stratejilerin somut tezahürleri olarak karşımıza çıkmaktadır.

Gramsci'nin hegemonya kuramı ve Althusser'in ideolojik aygıtlar, yaklaşımı çerçevesinde yapılan analizler, sporun görünüşte tarafsız bir alan olmasına rağmen otoriter rejimlerde doğrudan siyasal kontrol ve yönlendirmeye tabi olduğunu ortaya koymuştur. Bu bağlamda spor; sadece baskının değil, rızanın da üretildiği bir ideolojik üretim alanı haline gelmiştir.

Özellikle Nazi Almanyası, Sovyetler Birliği ve Putin sonrası Rusya örneklerinde, sporun lider figürüyle özdeşleştirilerek iktidarın karizmasını pekiştirdiği, geniş kitleleri seferber eden kitlesel etkinliklerin propaganda aracına dönüştüğü ve sporun ulusal kimliğin görsel ve kültürel inşasında işlevsel bir rol üstlendiği görülmüştür. Ayrıca yumuşak güç stratejileri bağlamında Çin, Katar ve Rusya gibi ülkelerde sporun, dış politika aracı olarak kullanıldığı, rejimin insan hakları eleştirilerine karşı meşruiyet üretiminde başat bir rol oynadığı dikkat çekmektedir.

Öneriler

Gelecek araştırmalarda, farklı rejim türleri arasında (demokratik, yarı-demokratik ve otoriter) spor politikalarının karşılaştırmalı analizi yapılabilir. Böylece sporun siyasal işlevleri arasındaki farklar daha sistematik biçimde ortaya konabilir.

Spor medyasının tekelleşmesi üzerine odaklanan çalışmalar, medya içeriği analizleriyle desteklenerek, rejim söylemleri ile sporcu temsil biçimleri arasındaki ilişkiyi derinlemesine incelenebilir.

Gençlik spor programları ve okul sporları, otoriter rejimlerin ideolojik formasyon mekanizmaları içinde özel bir yer tutmaktadır. Bu alan, sporun eğitim sistemi üzerinden nasıl ideolojik yönlendirme aracı olarak kullanıldığına dair daha fazla araştırma yapılabilir.

Sporun kadınlar, etnik gruplar veya muhalif sporcular üzerindeki etkisi, mevcut literatürde sınırlı olduğu görülmüştür. Rejimlerin toplumsal cinsiyet politikaları ile spor ilişkisi, otoriter yapılar özelinde detaylı incelenebilir.

Politika yapıcılar ve uluslararası spor örgütleri, sporun siyasal araçsallaştırılmasına karşı daha şeffaf ve denetleyici politikalar üretmelidir. Özellikle mega etkinliklerin düzenleyici kurumları, ev sahibi ülkelerin insan hakları, ifade özgürlüğü ve medya bağımsızlığı gibi kriterlere uymalarını gözetmelidir.

Sonuç olarak, sporun yalnızca kültürel bir etkinlik ya da fiziksel rekabet alanı olmaktan öte, otoriter rejimlerde siyasal iktidarın yeniden üretildiği, meşruiyetin pekiştirildiği ve ideolojik yönlendirmelerin gerçekleştirildiği çok katmanlı bir hegemonya alanı olarak işlev gördüğü sonucuna ulaşılmıştır. Bu kapsamda sporun; siyaset bilimi, iletişim çalışmaları, kültürel çalışmalar ve uluslararası ilişkiler gibi disiplinler arası çerçevelerle birlikte analiz edilmesi, bu olgunun bütüncül biçimde kavranabilmesi açısından önem arz etmektedir.

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PROBLEMS IN TEACHING TURKISH AS A FOREIGN LANGUAGE IN JORDAN[1]

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ABSTRACT

Turkish is a significant world language, both culturally and linguistically, due to its rich history, extensive vocabulary, and extensive geography. Consequently, the discipline of teaching Turkish to foreigners has gained considerable importance. In today's globalised world, the interaction between languages and the rise of multilingualism are becoming increasingly significant. Teaching Turkish as a foreign language has attracted growing interest, particularly in Middle Eastern countries, with Jordan being a focal point of this interest. The demand for learning Turkish in Jordan is escalating daily. This study highlights the importance of teaching Turkish as a foreign language in response to the increasing need for multilingualism in a globalising world. It aims to thoroughly examine the challenges encountered in this process within Jordan. The research employs phenomenology, a qualitative research design, and involves semi-structured in-depth interviews with 11 instructors of Turkish as a foreign language working in Jordan. The growing demand for the Turkish language in Jordan can be attributed to several factors, including Turkey's relations with Middle Eastern countries, the popularity of Turkish TV series and films, the increase in tourism activities, and the interest in Turkish universities. This surge in demand has led to the widespread teaching of Turkish in the country. However, various challenges have been identified, including differences in language structure, insufficient teaching materials, a teacher shortage, and low student engagement.

Keywords: Jordan, Teaching Turkish to Foreigners, Turkish.

[1] This paper is based on the thesis titled ‘Examination of Problems in Teaching Turkish as a Foreign Language in Jordan.’

Introduction

In today's world, where globalisation and intercultural interactions are intensifying, learning different languages has become not only a communicative skill for individuals but also a social, economic and cultural necessity. In this context, the teaching of Turkish as a foreign language has gained increased importance with Turkey's growing influence in the international arena and the global dissemination of its cultural products. The global popularity of Turkish TV series, films, literary works, and other artistic elements is a key factor driving interest in the Turkish language (Gürgendereli, 2023; Uçak & Yazıcı Şahin, 2023; Uluçay, 2023).

Turkey's historical, economic, and cultural ties with Middle Eastern countries play an important role in increasing the demand for learning Turkish in this region. The shared history and cultural ties inherited from the Ottoman Empire have created a strong foundation for relations between Turkey and Middle Eastern countries. In this context, Turkish is seen not only as a language but also as a historical bridge and cultural link in countries such as Jordan. Economic relations are another critical factor supporting this demand. Turkey's increased trade cooperation with Jordan, the active role of Turkish companies in the Jordanian market, and the intensification of tourism activities between the two countries have further increased the need to learn Turkish. In addition, the opportunities offered by Turkey in the field of education, particularly the support provided to Jordanian students through the Turkey Scholarships Programme, have increased the number of Jordanian youth seeking to study at Turkish universities and further strengthened interest in the Turkish language. When all these factors are taken together, it is clear that Turkey's historical, economic and cultural ties have significantly increased the demand for Turkish language learning in Jordan at both the individual and institutional levels (Kırbaş, 2019).

Jordan is a key focus point for teaching Turkish as a foreign language. The development of economic and cultural cooperation between Turkey and Jordan has increased the motivation of Jordanian students to learn the Turkish language. The increase in the number of Jordanian students who want to study at Turkish universities shows that Turkish has become a necessity in this country. Additionally, institutions such as the Turkish Scholarships Programme and the Yunus Emre Institute are undertaking significant efforts to support Turkish language education in Jordan. However, despite these positive developments, the teaching of Turkish as a foreign language in Jordan faces various challenges. These challenges range from insufficient teaching materials to teachers' lack of pedagogical knowledge and students' motivation problems.

Aim

The primary objective of this study is to thoroughly investigate the challenges encountered in teaching Turkish as a foreign language in Jordan. In this regard, the aim is to identify various problems encountered in the language learning process. In addition, the causes of these problems have been analysed and solutions proposed.

Method

This research is a qualitative study designed to examine the challenges encountered in teaching Turkish in Jordan. The study uses a phenomenological design. Phenomenology is a qualitative research approach that aims to understand individuals' experiences of a particular phenomenon and reveal the essence of these experiences (Moustakas, 1994). This design provides an appropriate framework for exploring teachers' personal experiences of the challenges they encounter in teaching Turkish and the deeper meanings behind these experiences. The phenomenological design employed in this study utilised an explanatory phenomenological approach. Explanatory phenomenology seeks to foster a profound understanding of individuals'

experiences and uncover the common themes that emerge from these experiences (Smith et al., 2009). In this study, semi-structured interviews with teachers enabled a detailed examination of these experiences.

Findings

As a result of the interviews conducted within the scope of the research, three main themes were identified regarding the teaching of Turkish in Jordan. The problems of teaching Turkish in Jordan were examined under three main sub-themes: language-related difficulties, educational environment problems, and student motivation. Language-related difficulties are significant obstacles that students encounter in the language learning process. These difficulties can be addressed in a wide range, from pronunciation problems to structural differences in the language. Two codes were identified for the sub-theme of language-related difficulties: structural differences in the language and pronunciation problems. The sub-themes of language structure differences and pronunciation problems were derived from the views of almost all participants. Since Turkish is an agglutinative language, it can be complex for students with different language structures, such as Arabic. Students may find it particularly difficult to learn language structures. The views of the instructors named Veli and Rahman exemplify this idea:

> In Jordan, Arabic is our native language, so when we learn a foreign language, the first thing we need to do is look at the family to which that foreign language belongs. Examining both Arabic and Turkish, Arabic is a Semitic language, while Turkish is an Altaic language. The difficulties start here. Since they belong to different families, each language has distinct characteristics. (Veli)

> The grammatical structures and linguistic differences between Turkish and Arabic were particularly challenging for students, especially the agglutinative language structure and sound harmonies, which required time for them to become accustomed to. In terms of agglutinative language structure, since Turkish is an agglutinative language, suffixes are added to words and phrases to create new meanings and convey new ideas. Arabic, on the other hand, is a root-based language, so the logic of word formation is very different. Students struggle to learn both the correct order and usage of suffixes in the Turkish language. For example, the suffix ‘da, de’ is used in Arabic at the beginning of the word. In Turkish, we say ‘okulda.’ The suffix comes at the end of the word, but in Arabic, it comes at the beginning of the word. When students speak, especially when they first learn Turkish, they say things like ‘da okul, da üniversite.’ (Rahman)

This study examines the educational environment in Jordan. In this context, issues specific to Jordan are discussed under this sub-theme. Inadequate educational materials and resources can negatively affect students' learning processes. Lack of technological equipment can reduce learning opportunities, notably by limiting access to digital resources. The views of the instructor, known as Hakan, illustrate this situation:

> The classes are crowded, and from a physical standpoint, there is a need for a separate building designed for different languages, with U-shaped tables. We need classrooms where we can hang Turkish materials. Another problem is that students have to walk too far within the faculty. After leaving one class, they have to go to another class that is very far away, which is difficult for the students. They come tired from one class and go to another, for example, they leave an English class and go to a Turkish class, which tires them both mentally and physically. Additionally,

> I believe it would be beneficial to have a separate Turkish building where Turkish is spoken. What is needed here is a complex. (Hakan)

Student motivation is a significant obstacle that is often encountered in language learning. This sub-theme addresses students' lack of motivation, uncertainty about their goals, and fear of making mistakes in the language learning process. Students' inability to clarify their language learning goals can lead to a lack of motivation. Clear goals enable students to focus more on their learning processes. The views of instructors Yaprak and Rahman support this idea:

> Some students may not have a clear goal in mind when learning the Turkish language. This can lead to a loss of motivation in the language learning process. Students who link language learning to educational or job opportunities in Turkey appear to be more motivated, while those without this goal may progress more slowly. (Yaprak)

> Some students lack sufficient motivation to learn the Turkish language. They are unaware of the advantages or opportunities of learning Turkish. I can explain it like this: the student asks, 'What will happen if I learn Turkish or if I don't learn it?' What will I do with this diploma after graduation? Where will I work? I will exhaust myself for three or four years, and after graduation, I will not be able to work anywhere with this diploma. Even if there are places to work, there are few of them, so I don't need to learn. When they think this way, it becomes challenging to engage them in conversation and teach them the Turkish language. (Rahman)

Conclusion and Recommendations

This study aims to comprehensively analyse the problems encountered in the process of teaching Turkish as a foreign language in Jordan and the solutions developed by teachers to address these problems. Conducted within the framework of qualitative research methods, this case study aims to reveal the fundamental difficulties and potential for improvement in the field by thoroughly examining the experiences of Turkish teachers in Jordan.

The study's findings reveal that Turkish language teaching in Jordan faces challenges in multiple dimensions. The data obtained from the teachers' perspectives were grouped under three main themes: language-related difficulties, educational environment problems, and student motivation.

The findings of this study are consistent with various studies conducted in the field of Turkish language teaching as a foreign language within the country. For example, studies conducted by Islıoğlu (2015) and Can (2023) also emphasised the problems encountered in grammar and writing skills. In addition, researchers such as Akyürek (2021) and Memiş (2021) have also highlighted issues, including the shortage of qualified teaching staff and inadequate materials. This situation suggests that the problems in the Jordanian context are similar to the common difficulties encountered in teaching Turkish as a foreign language in general.

The methodological approach of the study is based on a qualitative design that allows for an in-depth understanding of the experiences of Turkish teachers in Jordan. The thematic analysis of the data obtained through semi-structured interviews systematically revealed the fundamental problems in the field and the teachers' suggestions for addressing these issues. However, the fact that the research focuses primarily on the instructor's perspective and does not fully reflect the student's perspective can be considered a limitation. Future research that also examines

students' experiences may provide a more comprehensive picture. Furthermore, the study's limited context to Jordan restricts the generalizability of the findings to other countries.

Based on the findings of this study regarding the challenges faced in teaching Turkish as a foreign language in Jordan, several recommendations can be made.

First, it is essential to develop and provide learners with adequate teaching materials tailored to their needs. This includes creating textbooks, multimedia resources, and digital content that reflect the cultural and linguistic contexts of both Turkey and Jordan.

Additionally, continuous professional development should be offered to Turkish language instructors. Workshops and training sessions focusing on pedagogical strategies, language acquisition theories, and the specific challenges of teaching Turkish to Arabic speakers can enhance teaching effectiveness.

Improving educational environments is also crucial. Academic institutions should invest in creating dedicated language learning spaces equipped with the necessary technological tools and resources that facilitate interactive learning.

To foster student motivation, it is essential to communicate the benefits of learning Turkish. Informational sessions highlighting career opportunities, cultural exchanges, and the advantages of bilingualism in today’s globalised world can significantly enhance student engagement.

Establishing cultural exchange programs between Turkey and Jordan can provide students with immersive experiences. Such initiatives allow learners to engage directly with the language and culture, thereby increasing their interest and motivation to learn.

Incorporating technology into language learning can also improve student engagement. Online platforms, language learning applications, and virtual classrooms can offer flexible and interactive learning experiences.

Finally, future research should include the perspectives of students to gain a comprehensive understanding of their experiences and challenges in learning Turkish. This approach can inform more effective teaching strategies and curriculum development.

By implementing these recommendations, the teaching of Turkish as a foreign language in Jordan can be significantly improved, ultimately leading to better learning outcomes for students.

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ENERGY JUSTICE AND THE SOCIAL DETERMINANTS OF HEALTH: A CRITICAL EXAMINATION OF THE IMPACT OF ENERGY POVERTY ON SOCIAL HEALTH

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ABSTRACT

This study adopts an interdisciplinary lens to examine energy poverty within the framework of the social determinants of health, focusing on the multifaceted consequences of unequal access to energy on individuals' physical, mental, and social well-being. Employing conceptual analysis, policy document review, and critical interpretive methods, the research frames energy access not as a mere infrastructural deficiency but as a critical issue of social justice, public health, and environmental sustainability. Anchored in the principles of distribution, governance, and recognition, the study situates energy justice at the core of equitable energy transitions. Disadvantaged groups—particularly women, older adults, children, and low-income populations—are disproportionately burdened by limited energy access, which reinforces social exclusion and exacerbates health disparities. The analysis highlights the need to address the social dimensions of clean energy transitions under the notion of a "just transition" and underscores the importance of integrating energy policy with social protection and employment strategies to mitigate inequality. The strategic role of social work institutions is also explored, advocating for a shift from temporary relief to preventive and empowering service models. The study offers conceptual and practical insights toward recognizing energy access as a component of the right to health and integrating energy justice into public health strategies. While the absence of empirical data is acknowledged as a limitation, the work provides a theoretical foundation for future local and comparative research on vulnerable populations. Tackling energy poverty through multi-actor and holistic frameworks is no longer optional but an urgent imperative for building sustainable well-being and a more equitable society.

Keywords: Energy justice; Social determinants of health; Energy poverty; Social health inequalities; Social welfare policies; Just transition

ENERGY JUSTICE AND THE SOCIAL DETERMINANTS OF HEALTH: A CRITICAL EXAMINATION OF THE IMPACT OF ENERGY POVERTY ON SOCIAL HEALTH

ÖZET

Bu çalışma, enerji yoksulluğunu sağlığın sosyal belirleyicileri bağlamında disiplinlerarası bir yaklaşımla ele almakta ve enerjiye erişimdeki eşitsizliklerin bireylerin fiziksel, ruhsal ve toplumsal sağlık durumları üzerindeki çok boyutlu etkilerini incelemektedir. Kavramsal analiz, politika belgeleri incelemesi ve eleştirel yorumlayıcı değerlendirme yöntemleriyle yürütülen araştırma, enerji adaleti çerçevesinde dağıtım, yönetişim ve tanınma ilkelerini temel alarak enerjiye erişimin yalnızca altyapısal bir sorun değil; aynı zamanda sosyal adalet, halk sağlığı ve çevresel sürdürülebilirlik meselesi olduğunu ortaya koymaktadır. Özellikle kadınlar, yaşlılar, çocuklar ve düşük gelirli gruplar başta olmak üzere kırılgan toplulukların enerjiye erişimde yaşadıkları dezavantajlar, sosyal dışlanmayı ve sağlık eşitsizliklerini derinleştirmektedir. Araştırmada, temiz enerjiye geçiş süreçlerinin sosyal boyutları "adil dönüşüm" ilkesi kapsamında değerlendirilmiş, enerji politikalarının eşitsizlik üretme riskine karşı sosyal koruma ve istihdam politikalarıyla bütünleştirilmesi gerektiği vurgulanmıştır. Ayrıca sosyal hizmet kurumlarının bu alandaki stratejik rolü tartışılmış; enerji yoksulluğunun yalnızca geçici yardım uygulamalarıyla değil, önleyici ve güçlendirici sosyal hizmet modelleriyle ele alınması gerektiği savunulmuştur. Çalışma, enerjiye erişimin sosyal bir sağlık hakkı olarak tanınması ve enerji adaletinin halk sağlığı stratejilerine entegre edilmesi yönünde kuramsal ve pratik katkılar sunmaktadır. Saha verisiyle desteklenmemiş olması araştırmanın sınırlılığı olarak değerlendirilmekle birlikte, gelecekte kırılgan gruplar üzerinde yapılacak yerel ve karşılaştırmalı çalışmalar için kavramsal bir temel sunmaktadır. Enerji yoksulluğuyla mücadelenin, sürdürülebilir refah ve adil bir toplum inşası açısından çok aktörlü ve bütüncül yaklaşımlarla ele alınması artık ertelenemez bir gerekliliktir.

Keywords: Energy justice; Social determinants of health; Energy poverty; Social health inequalities; Social welfare policies; Just transition

1. Introduction

Health is a complex and multidimensional phenomenon that cannot be reduced solely to biological characteristics or access to healthcare services. A growing body of academic literature demonstrates that individual health outcomes are significantly shaped by social determinants such as living environment, socioeconomic status, education level, housing conditions, and access to energy (Daniel et al., 2018; Frank et al., 2020; Köktaş & Selçuk, 2018; Marmot, 2005). In particular, access to energy plays a central role in meeting basic human needs, directly affecting rights related to heating, lighting, hygiene, food preservation, and participation in digital services (Durmus Senyapar et al., 2024; Pehlivanoğlu & Yilmaz, 2022; IEA, IRENA, UN, World Bank and WHO, 2024).

Energy poverty refers to the condition in which individuals lack sufficient or any access to energy services (Maxim et al., 2016). It can be defined either as the inability of a household to meet basic energy needs (e.g., heating, lighting, cooling) for physical or financial reasons, or as having access to energy infrastructure without the capacity to benefit from it adequately (Emre et al., 2023; Middlemiss, 2022). In Turkey, inequalities in energy access are particularly pronounced among low-income individuals, rural populations, and other disadvantaged groups, limiting their ability to maintain basic living standards (Kose, 2019). These disparities not only reflect energy injustice but also exacerbate health inequalities, as economic activities based on carbon-intensive growth contribute to climate-driven health burdens among vulnerable populations (İpek & İpek, 2024; Yılmaz, 2022; TUIK, 2024).

Households experiencing energy poverty often face difficulties allocating sufficient resources to essential energy services due to low income and high energy costs (Xu & Chen, 2019). This results in compromised domestic energy practices related to heating, cooling, and cooking, often forcing households to cut spending on health, education, social engagement, or nutrition, or to resort to unhealthy and polluting energy sources. Urgent policy measures are needed, such as promoting energy-efficient buildings and renewable energy sources tailored to local dynamics (Öcal & Başarslan-Arslan, 2022; Tuğaç, 2022). Ensuring justice in energy production, distribution, and consumption, and guaranteeing equitable representation of vulnerable groups in these processes, is imperative. Yet, accessibility cannot be defined merely by the physical or geographic availability of energy services. When evaluated alongside equity and continuity, accessibility must also ensure that individuals can benefit from energy services at a reasonable and affordable cost (Durmus Senyapar et al., 2024; PehliVanoğlu & Yilmaz, 2022; IEA, IRENA, UN, World Bank and WHO, 2024).

From the perspective of energy policy, Turkey appears to have made significant progress in ensuring access to energy in alignment with Sustainable Development Goal 7. However, several structural and political barriers remain. The pace of renewable energy investment has not kept up with national targets, exposing the tension between economic growth and environmental sustainability. This signals both a bottleneck and a potential pathway forward (Telli & Ozkan, 2024). Furthermore, renewable energy, which holds strategic importance for sustainable development, is also a critical determinant of public health (Ecevit et al., 2022). Recognizing access to energy as a fundamental human right is no longer confined to environmental policies—it has become central to social welfare agendas. As affirmed by the European Social Charter and the United Nations' 2030 Sustainable Development Goals (SDG 7), ensuring access to affordable, reliable, sustainable, and modern energy for all is a prerequisite for a healthy life (UNDP, 2025). Thus, addressing energy poverty requires not only infrastructural interventions but also an integrated policy framework grounded in social justice, equity, and public health.

Although energy poverty is typically framed in technical and economic terms, its direct and indirect effects on public health remain underexplored in the social policy literature. Among low-income and vulnerable groups, lack of access to energy leads to a cascade of negative outcomes, ranging from respiratory illnesses and psychological distress to social exclusion and educational inequality. Therefore, energy access must be reframed as both a matter of social justice and a right to health. This study contributes to the literature by linking energy poverty with public health and social work from the perspective of energy justice. By outlining the strategic role of social work institutions in addressing energy-related inequalities, the study also offers policy-relevant insights for practitioners and decision-makers.

The aim of this research is to provide a conceptual analysis of energy poverty through the lens of the social determinants of health, and to critically evaluate health inequalities from the perspective of energy justice. It further seeks to explore how principles of a "just transition" can inform health policy by incorporating the social dimensions of clean energy transitions. In this context, the study addresses the following research questions:

1. How does energy poverty affect individuals' physical and mental health in relation to the social determinants of health?
2. How can energy justice—through the dimensions of distribution, governance, and recognition—be linked to public health policies and social work practices?
3. In what ways is social justice overlooked in energy transition processes, and what risks does this pose for vulnerable populations?
4. What strategic roles should social work institutions assume in addressing energy poverty, and how can they foster socially innovative responses?
5. How can the integration of energy poverty into public health strategies contribute to the restructuring of social welfare policies?

In addition to its conceptual contributions, this study also provides practical recommendations for policymakers, local governments, and social work institutions. Concrete proposals are developed to restructure energy assistance programs through a rights-based approach, expand social aid mechanisms to include energy poverty, and enhance the operational roles of social services. The study also proposes the development of an "Energy Support Index" and the establishment of "Energy Social Work Units" within municipalities, offering structural recommendations to promote inclusive and sustainable social welfare systems based on energy justice.

2. Conceptual Framework

2.1. Social Determinants of Health: Income, Housing, Environment, and Access to Services

Social determinants of health refer to the social and structural conditions that individuals are exposed to throughout their lives, which affect their health status, functionality, and overall quality of life (Daniel et al., 2018; Frank et al., 2020; Köktaş & Selçuk, 2018; Marmot, 2005). These determinants range from individual-level characteristics to systemic factors and play a crucial role in shaping health inequalities. Under conditions of poverty, these determinants become even more pronounced, and disadvantages in areas such as education, income, housing, environmental conditions, and access to healthcare deepen health disparities.

In recent years, poverty has increasingly been understood not merely as a lack of income but as a multidimensional phenomenon involving deterioration in health status, limited access to education, and inadequate living conditions (Putri et al., 2024). It has been emphasized that poverty contributes to poor health indicators, the spread of infectious and chronic diseases, preventable early mortality, and adverse outcomes in child health—all of which may have intergenerational impacts (Güler et al., 2022). Furthermore, studies have shown that low health literacy—often resulting from a limited understanding of diseases and treatments—constitutes an independent risk factor for poor health outcomes. In this regard, health literacy plays a critical role in advocacy and in the delivery of equitable, justice-oriented health services, especially within strategies to combat poverty (Gözlü, 2020).

2.2. Energy Poverty: Definition, Measurement Methods, and Social Implications

Energy poverty is a multidimensional social issue that arises when individuals are unable to access essential energy services due to economic, technical, or infrastructural constraints, thereby experiencing a decline in their overall quality of life (Okushima, 2017). It stems from a combination of barriers, primarily financial and technical, that hinder access to basic energy needs and directly impact living standards. In the Turkish context, energy poverty is often associated with low income levels and is typically measured using indicators such as the share of household energy expenditures in total income (Dogan et al., 2021). However, income-based approaches alone are insufficient for capturing the complexity of energy poverty (Kose, 2019). This form of deprivation is also shaped by high energy prices, inadequate infrastructure, regional disparities, and frequent interruptions in energy supply.

In Turkey, data on energy poverty largely rely on subjective indicators, such as self-reported experiences of insufficient heating (İpek & İpek, 2024). Common metrics include the ratio of energy spending to household income, the energy efficiency of dwellings, and the prevalence of households living in inadequately heated homes (Üstündağlı Erten et al., 2023). These limitations point to the necessity of adopting more comprehensive and multidimensional approaches for measuring energy poverty (Isazade & Altan, 2023).

Beyond its physical consequences, energy poverty profoundly affects mental health, social participation, and educational attainment. One key concern in the literature is that cold, dark, and uncomfortable living conditions resulting from energy deprivation may trigger psychological distress such as anxiety, stress, and depression (Bègue et al., 2022). Students who lack proper heating and lighting conditions for studying face compounded educational inequalities (Sule et al., 2022). Given that social interaction largely occurs within domestic environments, energy-poor households often withdraw from social activities such as hosting guests, engaging in community life, or accessing digital tools. Energy poverty, therefore, must be addressed not only as an economic issue but also as a social, psychological, and cultural concern.

As a problem with far-reaching economic, social, and environmental ramifications, energy poverty increasingly intersects with public health and social justice concerns in the context of sustainable development (Lee & Yuan, 2024). As highlighted in the Brundtland Report, societies where poverty is widespread are more susceptible to ecological crises (UN, 1987). Deprived of access to modern energy services, poor populations are often forced to overexploit environmental resources, which in turn accelerates ecological degradation and further undermines their quality of life (Adom et al., 2021). This vicious cycle jeopardizes not only the environment but also access to basic human needs. Consequently, inadequate distribution of resources and the failure to achieve sustainable development goals deepen social inequality and transform energy poverty into a broader issue of social justice (Özgenç, 2015).

2.3. Energy Justice: Principles of Distributional, Procedural, and Recognitional Equity

Energy justice is closely linked to environmental and climate justice and advocates for the fair distribution and sharing of energy services and benefits. It refers to a framework that aims to ensure fairness in the production, distribution, and consumption of energy. Distributional justice in energy involves the equitable allocation of energy resources across society. In Turkey, inadequate energy infrastructure in rural areas limits access to energy services for residents in those regions, reinforcing spatial and social inequalities (Durgun, 2024).

Procedural justice, in the context of regulatory frameworks, reveals significant shortcomings in democratic participation. An analysis of Turkey's energy security policies between 2000 and 2020 shows that decision-making processes were largely dominated by technical experts and political authorities. This has constrained public engagement—a core element of participatory democracy—and limited transparency in governance. Key institutions such as the Ministry of Energy and Natural Resources and the Energy Market Regulatory Authority (EPDK), along with affiliated agencies, have maintained a dominant role in policy formulation and implementation. As a result, societal actors and civil society organizations have had minimal involvement in energy governance. These conditions underscore the need to enhance citizen participation in decision-making and to strengthen mechanisms of transparency so that public interests can be better represented in energy policymaking (Koca & Yoldaş, 2022).

Recognitional justice calls for the acknowledgment of the specific needs of marginalized and excluded groups in energy policy. The rights of vulnerable populations—including older adults, persons with disabilities, and women—to access energy are rarely prioritized in social service frameworks or in climate justice agendas, despite the disproportionate burdens they face in the context of energy poverty and climate crises (Özkaya, 2024).

3. Methodology

This study is designed as a literature-based qualitative inquiry. In alignment with its primary aim, the research adopts a conceptual and critical approach to analyze the impact of energy poverty on the social determinants of health. Core concepts such as energy poverty, energy justice, health inequalities, and just transition are analytically framed within a structured conceptual framework.

The analysis is grounded in a comprehensive review of recent peer-reviewed articles, policy documents, and reports issued by international organizations. The literature was systematically reviewed thematically, with a temporal focus on sources published between 2015 and 2025. Within the Turkish context, official documents issued by relevant institutions, along with national policies on social services, social assistance, and energy support programs, were examined.

This review identified structural misalignments between the approaches to energy access reflected in policy documents and the mechanisms of social protection. Drawing on conceptual and policy analysis, the study interprets the causal linkages between energy poverty and public health outcomes from a critical social policy perspective. Particular attention is given to how vulnerable groups—such as women, the elderly, children, and residents of rural areas—are systematically excluded from energy access, and how this exclusion deepens existing social inequalities.

The limited institutional capacity and implementation challenges faced by social service organizations are also examined through the lens of rights-based policy frameworks and social innovation. This multilayered methodological strategy allows the study to go beyond theoretical

interpretation by offering original and actionable recommendations for restructuring energy policies in ways that promote health equity and social justice.

4. Thematic Analysis

4.1. Impacts on Physical Health

Energy poverty exerts a wide range of direct and indirect negative effects on physical health. One of the most pressing consequences is indoor air pollution resulting from limited access to clean energy (Pan et al., 2021). The use of solid fuels for cooking—common in energy-poor households—exposes family members, particularly women and children, to harmful particulate matter, increasing the long-term risk of chronic illnesses (Reyes et al., 2019). According to the World Health Organization, indoor air pollution is responsible for millions of premature deaths globally (Nwanaji-Enwerem et al., 2020). Additionally, the inability to sufficiently heat homes during winter due to lack of energy access contributes to cold-related illnesses and weakens the immune system (Straub, 2017). In this context, energy poverty is not merely a material deprivation but constitutes a significant public health risk and must be addressed as such in health policy frameworks

The consequences of inadequate energy consumption extend beyond heating and have critical implications for food security and the sustainability of agricultural production. Households with limited access to energy tend to rely on low-quality, long-shelf-life food products, as they often lack proper refrigeration (Candelise et al., 2021). Similarly, the ability to store medications under appropriate conditions is compromised. Agricultural activities—including irrigation systems, machinery, cold chains, and transportation—are heavily dependent on energy. Fluctuations in fossil fuel prices drive up production costs, adversely affecting both crop and livestock sectors, which leads to instability in food supply chains.

As highlighted in the study, rising energy prices contribute to stagnation in agricultural output, thereby restricting access to food and pushing prices upward (Radmehr & Rastegari Henneberry, 2020). Limited access to energy particularly undermines the competitiveness of small-scale producers in rural areas and amplifies the fragility of food systems. As a result, energy access not only influences production processes but also directly affects the availability, affordability, and sustainability of food, rendering it a critical determinant of food security (Candelise et al., 2021).

4.2. Mental Health and Psychosocial Impacts

Energy insecurity not only affects physical well-being but also has profound consequences for mental health. Insufficient heating and lighting trigger stress, anxiety, and feelings of helplessness among individuals (Campagna, 2016). Uncertainty in access to energy services disrupts daily routines and fosters a constant atmosphere of financial insecurity (Zhang et al., 2023). Low socioeconomic conditions are known to have a profound and multifaceted impact on psychological well-being (Evans, 2016). Individuals with low socioeconomic status (SES) are more frequently exposed to social and environmental threats, which negatively impact their emotional resilience and cognitive capacity (Kamilçelebi, 2024). The scarcity of material resources often leads to persistent uncertainty and helplessness, creating fertile ground for psychological disorders such as anxiety, stress, and depression (Ettman et al., 2024).

Low-SES individuals are more likely to experience other-oriented emotions—such as compassion, affection, and empathy—stemming from interdependent relationships developed as coping mechanisms under hardship (Liu et al., 2023). However, this form of social attachment can impede the pursuit of individual emotional fulfillment and may, over time, result

in psychological exhaustion (Gökdağ, 2021). From this perspective, addressing socioeconomic inequalities should not only aim to improve material welfare but should also be regarded as a strategic policy objective to enhance psychological well-being.

Poverty should be understood not merely as economic deprivation, but as a multidimensional phenomenon that threatens the psychological and social integrity of individuals (Alloush, 2024). With the intensification of socioeconomic inequality under globalization, urban populations living in poverty experience heightened feelings of exclusion, insecurity, and worthlessness. The erosion of emotional resources leads to the widespread emergence of psychological symptoms such as depression, burnout, and anger (Bianchi et al., 2017). In urban settings, spatial segregation exacerbates these dynamics by prompting the poor to compare their lives with wealthier groups, which intensifies psychological strain and may give rise to social envy, feelings of exclusion, and even tendencies toward collective violence.

Energy poverty further limits individuals' social interactions and weakens community bonds (Stojilovska et al., 2023). Among young people in particular, prolonged social isolation can negatively affect identity formation and the development of a sense of belonging.

4.3. Vulnerable Groups and Inequality

Energy poverty functions as a form of structural inequality that disproportionately affects vulnerable populations—particularly older adults, women, children, and low-income individuals—thereby exacerbating existing social vulnerabilities. In households with limited access to electricity and clean energy sources, children fall behind in their education, while older adults face heightened health risks due to inadequate heating conditions (Banerjee et al., 2021). Women, especially in rural areas, tend to rely more heavily on traditional cooking methods, which results in both time poverty and increased exposure to indoor air pollution caused by solid fuels (Imran & Ozcatalbas, 2020). This dual burden not only intensifies gender-based inequalities but also constrains women's productive roles in public life. As such, energy poverty must be addressed not solely as an economic issue but as a matter of social justice and human rights.

In addition, rural–urban disparities and regional inequalities reveal the spatial dimensions of energy poverty (Wan et al., 2024). In many rural areas, households continue to use traditional and unsafe energy practices, which heighten health risks for women and children in particular (Imran & Ozcatalbas, 2020). These practices further widen the gap between demographic groups and reinforce intergenerational cycles of inequality (Tuncer, 2019).

4.4. Social Justice in Energy Transition Processes

Although the transition to clean energy is a welcome development in terms of environmental sustainability, the social dimension of this transformation—if not adequately addressed—may give rise to new forms of inequality. Ensuring social justice within energy transition processes is essential to guarantee that the shift toward a low-carbon economy serves not only environmental goals but also advances social equity and decent work opportunities. The "just transition" framework emphasizes the principle that no one should be left behind during this process (McCauley & Heffron, 2018). It specifically calls for the protection of workers in fossil fuel industries, disadvantaged regions, and vulnerable social groups.

While the green economy is expected to generate employment in emerging sectors, it also entails potential job losses in others. Accordingly, active and passive labor market policies, reskilling programs, social protection mechanisms, and robust social dialogue platforms are vital to mitigating transitional risks and upholding social justice (Sage, 2015). Without such

measures, the uneven distribution of transformation costs may deepen existing inequalities and lead to broader social unrest (Görmüş, 2024).

Energy transition processes must therefore be approached not only through technical and economic lenses, but also with a focus on their social implications. This includes ensuring the participation of vulnerable groups and developing comprehensive policy tools—ranging from employment strategies to social support mechanisms. In Turkey, efforts have been made to strike a delicate balance between energy supply security and environmental sustainability within the broader development agenda (Kok & Benli, 2017). However, disparities in access to energy across different socioeconomic groups have not been sufficiently addressed in the transition process.

A truly sustainable development approach must go beyond ecological conservation to encompass fair access to energy services, inclusive participation in decision-making, and equitable distribution of benefits from technological transformation. In this regard, the equitable redesign of energy policies plays a crucial role in integrating social justice into the clean energy transition (Özekan, 2023).

5. Policy Discussion and Social Work Perspective

5.1. Should Energy Poverty Be Integrated into Social Welfare Policy?

Energy poverty refers to the inability of individuals to access sufficient energy to meet their basic daily needs (Faiella & Lavecchia, 2021). This condition is not merely an economic issue but fundamentally a matter of social justice. Transitioning social services toward a rights-based structure necessitates the inclusion of essential needs, such as energy access, within the scope of social welfare policy (Manasi & Mukhopadhyay, 2024). A historical examination of the development of social services in Turkey reveals that assistance efforts were long confined to a charitable framework (Acar & Polat, 2023). However, the modern conception of social work mandates professional interventions under the institutional responsibility of the state. Within this framework, energy poverty, like housing, education, and healthcare, must be treated as a basic human right and incorporated into the design of social service policies (Kyprianou et al., 2019). The recognition of energy poverty as an integral part of welfare policy is therefore essential (Reçber, 2019). Moreover, energy poverty is intrinsically linked not only to economic inequality but also to environmental injustice. In particular, developing countries face severe environmental and social consequences due to a lack of access to energy (Filho et al., 2025). Communities that lack access to modern energy services often resort to traditional and environmentally harmful sources such as biomass and coal for heating and cooking (Bruce et al., 2015). This exacerbates indoor air pollution, contributing to deforestation and declines in agricultural productivity, which in turn lead to a cascade of negative effects. As such, energy poverty is not simply a matter of individual living standards but a multidimensional phenomenon with direct implications for public health, educational equity, and environmental degradation.

Accordingly, the integration of energy poverty into social welfare policy has become imperative for achieving holistic progress in the domains of health, environment, education, and economic development (Ateş & Atay Polat, 2023). Incorporating energy poverty into the broader social assistance system could serve as a key instrument for enhancing the quality of life for disadvantaged groups (Best et al., 2021).

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Energy poverty refers to the inability of individuals to access sufficient energy to meet their basic daily needs. This condition is not merely an economic issue but fundamentally a matter of social justice. Transitioning social services toward a rights-based structure necessitates the inclusion of essential needs, such as access to energy, within the scope of social welfare policy (Frigo et al., 2021). A historical examination of the development of social services in Turkey reveals that assistance efforts were long confined to a charitable framework (Dorlach, 2015). However, the modern conception of social work mandates professional interventions under the institutional responsibility of the state. Within this framework, energy poverty, like housing, education, and healthcare, must be treated as a basic human right and incorporated into the design of social service policies. The recognition of energy poverty as an integral part of welfare policy is therefore essential.

Moreover, energy poverty is intrinsically linked to economic inequality and environmental injustice (Hassan et al., 2022). Developing countries face severe environmental and social consequences due to a lack of access to energy (Drago & Gatto, 2023). Energy poverty is not simply a matter of individual living standards, but a multidimensional phenomenon with direct implications for public health, educational equity, and environmental degradation. Consequently, integrating energy poverty into social welfare policy has become imperative for achieving comprehensive progress in the domains of health, environment, education, and economic development conditions (Banerjee et al., 2021). Incorporating energy poverty into the broader social assistance system could serve as a key instrument for enhancing the quality of life for disadvantaged groups.

5.2. Integrating Energy Justice into Public Health Strategies

Integrating energy justice into public health strategies is crucial for achieving environmental sustainability and promoting social equity, as well as the right to health. The principle of energy justice requires that energy policy be focused on achieving supply security and efficiency, and be designed to contribute significantly to public health outcomes (McMonagle et al., 2021). Once energy access is recognized as a human right, public health strategies must be restructured around this rights-based framework, with local energy assistance systems designed to reduce health disparities.

Energy justice should also be viewed as a social work issue, as it directly impacts individuals' quality of life. The social work profession is inherently multidisciplinary, to enhance individual well-being, secure social justice, and protect human rights (Şimşek & Altun, 2021). In this context, workplace-based social services and institutional corporate social responsibility efforts must address employees' psychosocial health and their environmental conditions (Macassa et al., 2021). Accordingly, access to clean, safe, and sustainable energy should be regarded as a fundamental right for which social workers must advocate. When public health strategies are aligned with energy justice, social work can offer both preventive and empowering interventions that improve living conditions and contribute to long-term sustainable development.

5.3. The Role of Social Service Institutions in Energy Assistance Policies

Social service institutions play a strategic role as providers of aid in the fight against energy poverty and as agents of social innovation. The growing necessity to implement innovative practices in social policy has positioned these institutions at the core of systemic transformation. Particularly in the context of public-sector-supported innovations, tackling a multidimensional issue like energy poverty requires inter-institutional collaboration and data-driven approaches

(Sareen et al., 2020). In this regard, the integration of digital technologies into unified information systems for social assistance delivery represents a major advancement. Such systems enhance the identification of those in need and increase the effectiveness of support (Kolokotsa, 2016). Leveraging these tools, social service institutions can transform energy assistance into preventive and empowering social policy instruments—an essential strategy for promoting sustainable welfare (Ates, 2020).

In Turkey, a range of public social assistance mechanisms has been implemented to address energy poverty. According to the Ministry of Family and Social Services' 2024 Annual Report, the "Türkiye Family Support Program" provided support amounting to 46.48 billion Turkish lira to approximately 3.6 million households (ASHB, 2025). However, the effectiveness of social assistance is not determined solely by its monetary value or frequency, but rather by whether it is delivered through an integrated and coordinated social service framework that involves local governments and institutional actors.

One of the major challenges in municipal social work is the fragmented structure of service delivery, with responsibilities scattered across various departments, leading to inefficiencies and role duplication (Yuen, 2020). The limited employment of professional social workers in municipalities, coupled with unclear job definitions and weak institutional coordination, hinders the effective targeting and delivery of social support (Heitmann, 2017). Yet an effective social assistance system requires sustainable coordination between municipalities, central government agencies, civil society organizations, and universities. To move beyond short-term relief and toward empowering, inclusion-oriented, and long-term welfare solutions, institutional cooperation and data-informed planning are of critical importance (Açıkgöz et al., 2024). Accordingly, energy support programs must be implemented in close coordination with social service institutions and local governments (Leonhardt et al., 2022). This will enable both more efficient targeting of support measures and monitoring of recipients' psychosocial well-being over time.

Within this framework, clearly defining the intervention areas of social service institutions in the context of energy poverty is essential for developing holistic policy solutions and effective implementation strategies (Jacques- Aviñó et al., 2022). Building on the thematic findings presented in earlier sections, the study provides an analytical overview that links the physical and mental health effects of energy poverty to corresponding social work interventions. The following table summarizes the key intervention areas for social service institutions in response to various manifestations of energy deprivation and their associated health-related consequences. This structure aims to offer a multidimensional and target-oriented roadmap for policymakers and practitioners.

Indicator of Energy Poverty	Physical Health Impact	Mental / Psychosocial Impact	Social Work Intervention Area
Inadequate home heating	Respiratory infections, increased risk of illness	Anxiety, depression, and social isolation	Fuel and energy assistance programs; assessment of indoor environmental conditions
Use of solid fuels / indoor air pollution	Asthma, COPD, cardiovascular diseases	Anxiety, long-term stress burden	Health education, referral to clean energy alternatives, and advocacy focused on women and children
High proportion of income spent on energy	Cutbacks in nutrition and medication	Perceived poverty, helplessness	Integration of social assistance and energy support programs
Lack of access to education and digital services (lighting, internet)	Poor academic performance, learning difficulties	Social exclusion, loss of belonging among youth	Child protection, educational support, and local solutions for digital inclusion
Intermittent energy access (frequent outages, restricted access)	Food spoilage, hygiene issues, and improper storage of medication	Fear for the future, insecurity	Crisis intervention services, local monitoring of energy security, and coordination of social service networks
Exclusion from clean energy transition processes	Resorting to harmful alternatives, exposure to environmental risks	Lack of political representation; structural exclusion	Ensuring representation of vulnerable groups in just transition planning, participation in policymaking

6. Conclusion and Recommendations

This study has approached energy poverty through an interdisciplinary lens within the framework of the social determinants of health, revealing its multidimensional impacts on physical, mental, and social well-being. The lack of access to energy, particularly among vulnerable groups, emerges as a structural issue that deepens social exclusion and threatens public health. The findings demonstrate that energy poverty is not merely a matter of technical infrastructure or economic insufficiency; rather, it is closely tied to social justice, human dignity, and the inclusiveness of public policy. From an energy justice perspective, the analysis highlights the need for energy policies to be restructured not only around supply security and efficiency but also with a rights-based, participatory, and environmentally sustainable orientation.

The study emphasizes the crucial role of social service institutions in implementing preventive and empowering policy tools to combat energy poverty. Key recommendations include recognizing energy access as a social right to health, managing energy assistance through data-driven mechanisms, and integrating support into local governance through social municipalism. Proposals such as the development of an Energy Support Index and the establishment of Energy Social Work Units within local governments offer concrete and actionable roadmaps for enhancing institutional capacity and promoting sustainable social welfare.

Nevertheless, a primary limitation of this study is the absence of field data. It does not incorporate qualitative or quantitative analyses that reflect individual experiences of energy poverty. Conducted through conceptual and policy analysis, the research follows a literature-based framework and does not include empirical comparisons. This necessitates caution in interpreting the findings across different local contexts.

Future research should prioritize regional field studies on energy poverty, including in-depth analyses of access experiences among vulnerable groups and evaluations of policy outcomes through impact assessment models. Special attention should also be given to the unique barriers faced by children, women, older adults, and persons with disabilities in accessing energy,

through interdisciplinary investigations that can inform more comprehensive policy development.

In this regard, energy access must be acknowledged not as a purely technical concern, but as a fundamental right situated at the intersection of social welfare, public health, and environmental responsibility. Addressing energy poverty is no longer the sole domain of social workers or environmental engineers—it must become a shared responsibility among local administrators, urban planners, public health professionals, and policymakers. A holistic and inclusive transition grounded in energy justice is not only essential for mitigating today's inequalities but also key to building a more equitable future.

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TESTS FOR THE SAFE NAVIGATION OF ELECTRIC VEHICLES ON HIGHWAYS

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ABSTRACT

Most of the world's energy needs are met from fossil sources. However, the gases released by the gradual decrease in fossil resources and the combustion of fuels obtained from these sources have negative aspects such as environmental pollution, acid rain or global warming. Therefore, the demand for electric vehicles is increasing, especially in the automotive industry. Due to the increasing demands, many different types of electric vehicles are produced.

With the rapidly developing technology, the establishment of standards and tests for electric vehicles has become an important issue for the widespread adoption and success of electric vehicles. Safety standards address the potential risks associated with electric vehicles, including electrical hazards, fire prevention, collision safety, and emergency response protocols. Compliance with safety standards builds consumers' trust and confidence in electric vehicle technology.

In this study, the history of electric vehicles, various types and tests performed according to standards in electric vehicles are included. In order to make the study more efficient, Battery Vibration Test and Test Standards for Electric Vehicles, Leak Tests in Electric Vehicles, Safety Tests in Electric Vehicles, Efficiency test and analysis of electric vehicles were examined under 4 main headings.

Keywords: Electric vehicle, safety tests, highways.

Introduction

Electric cars emit less carbon dioxide into the environment and play a significant role in combating air pollution. At the same time, they have higher energy efficiency. The cost of electric cars is generally higher compared to fossil fuel vehicles. However, it is expected that costs will decrease with advancements in battery technologies and incentives. Electric cars have many advantages. They provide a quieter ride, produce less vibration, and offer lower operating costs. Additionally, electricity is a cheaper and more stable energy source. One disadvantage of electric cars is the currently limited charging infrastructure. The spread of charging stations and the development of fast charging technologies could solve this problem. The range of electric cars is increasing with advancements in battery technologies. Now, many electric cars can travel long distances of 300-400 km on a single charge (Bediroğlu & Gencer, 2024).

Governments and car manufacturers are promoting the widespread adoption of electric vehicles. Policies such as tax advantages, incentives, and low emission zones aim to increase the use of electric cars. Electric vehicles are considered a part of a sustainable future. Given the depletion of fossil fuels and their environmental impacts, electric vehicles are expected to play a significant role in the energy transition. The combination of electric cars with autonomous driving technologies is also anticipated. While autonomous driving offers significant advantages in terms of safety and comfort, it can further enhance the energy efficiency of electric vehicles (Ustabaş, 2014).

Standards determine the emissions, energy efficiency, energy consumption, performance, range, speed, and charging time of electric vehicles. They are also used to assess the safety and environmental impacts of electric vehicles. Topics such as battery performance of electric vehicles, safety of electrical systems, and vehicle recycling are also evaluated within these standards. Thanks to these standards, electric vehicles can be used more safely, in an environmentally friendly, and performance-efficient manner. At the same time, they promote competition among manufacturers and support technological developments in the industry (Menak et al, 2021).

An electric car is a vehicle that is driven using one or more electric motors by utilizing electricity stored in batteries and other energy storage devices. Electric motors provide instant torque and enable powerful and balanced acceleration. There are various types of electric cars. The most common are fully electric cars (Battery Electric Vehicles - BEV) and Plug-in Hybrid Vehicles (Plug-in Hybrid Electric Vehicles - PHEV) (Ediz, 2017).

Fully electric cars operate solely on electric motors and draw energy from batteries. These vehicles offer a zero-emission driving experience and typically use large batteries that have a longer range. Fully electric cars can be charged at charging stations or from home electrical outlets. The charging time varies depending on the battery capacity and the type of charger used (Markel and Simpson, 2007). Figure 1 shows the drive system of an electric vehicle.

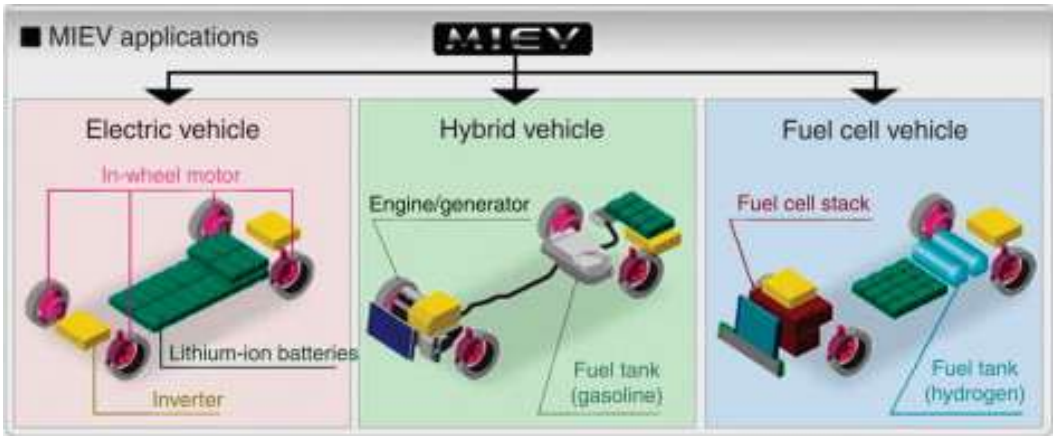


Figure 1. Electric drive systems in electric vehicles (Gutmann, 2009)

As seen in Figure 2, the first electric vehicle produced in the world was invented by Thomas Davenport in Vermont, America in 1835 (Segrave, 2019).



Figure 2. Thomas Davenport First Electric Vehicle

The first electric car in Turkey was ordered by II. Abdulhamid from Messrs Immisch & Co in England in 1888. This car, specially designed by the company's engineers Magnus Volk and Moritz Immisch, had two closely positioned small wheels instead of one large wheel at the front and was equipped with a 20 Ampere 48 Volt 1 horsepower motor patented by Immisch. Abdulhamid was very pleased with this car and rewarded both engineers, which allowed them to gain international fame (Akandere & Öztürk, 2024).



Figure 3. The first electric vehicle in Turkey made for Abdulhamid II by Messrs Immisch & Co (Segrave, 2019)

1888: Andreas Flocken's four-wheeled electric vehicle is shown in Figure 4. It had a high iron-wheeled wagon with an electric motor that transmitted about 0.9 kW (1 hp) power. The wooden vehicle reached a maximum speed of 15 km/h and weighed 400 kg (882 lb) (Seely, 2002).



Figure 4. Andreas Flocken's four-wheeled electric vehicle (Seely, 2002).

Electric Vehicle Types

- **Electric Vehicles (EVs)**

Unlike internal combustion engine vehicles, electric vehicles use the electrical energy they draw from the battery instead of requiring fuel combustion to start the engine. The capacity of the battery determines the range of this type of electric car, which is the distance it can travel on a single battery charge (Gürbüz & Kulaksız, 2016). Figure 5 shows the entirely electric vehicle battery and motor group.

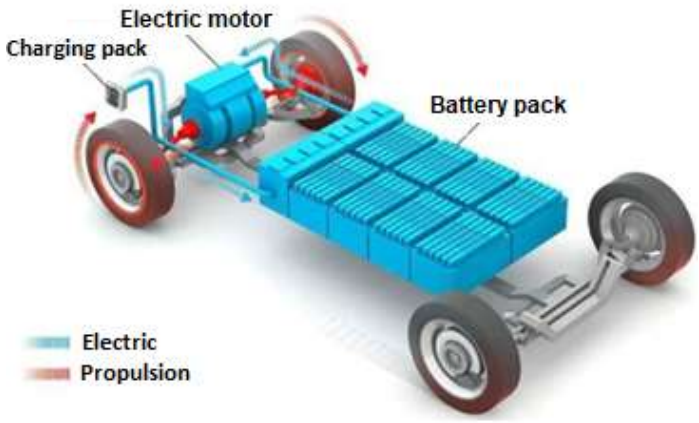


Figure 5. Fully electric vehicle interior structure (Kül, 2023)

- **Hybrid Electric Vehicles (HEVs)**

The concept of a hybrid car refers to vehicles that have both an internal combustion engine and an electric motor. The fuel engine and electric motor in hybrid vehicles work together to provide movement. Typically, the electric motor is active when the vehicle is progressing at a steady and slow speed. As the speed of the vehicle increases, the fuel engine either engages alone or works in conjunction with the electric motor (Formentin, 2021, Zia, 2016). The operation of the hybrid electric vehicle is shown in Figure 6.

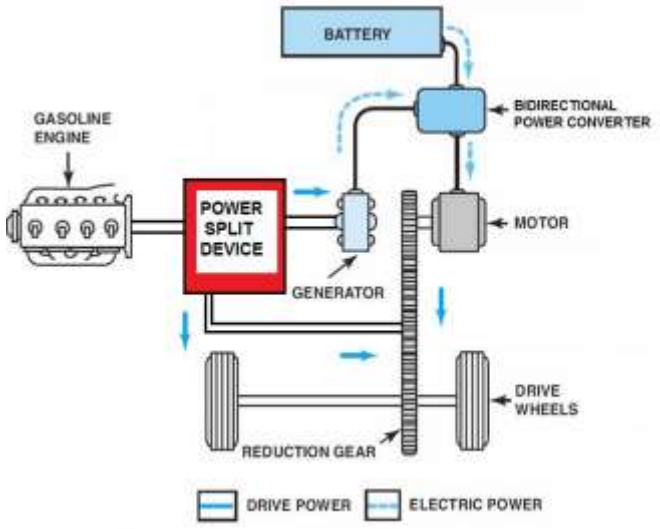


Figure 6. Hybrid Electric Vehicles (HEVs) (Zia, 2016)

- **Mild Hybrid Electric Vehicles (MHEVs)**

Mild hybrid vehicles are cars equipped with electric technology that supports the engines of traditional internal combustion engine vehicles, regardless of whether they have gasoline or diesel engines, and reduces fuel consumption. This support electric motor takes over the role of the starter motor in the car and usually uses a 48-volt battery (Dvadnenko & Dziubenko, 2023).

Mild hybrid cars can start moving with the electric energy they contain, without the need to ignite fuel, and respond faster compared to their competitors. At the same time, they reduce overall costs by not consuming fuel at low speeds. When your vehicle requires more power while cruising, it allows you to obtain extra power by engaging the electric motor, providing high performance. Additionally, it keeps your fuel consumption at an optimal level. During deceleration, the 48-volt hybrid battery is charged, ensuring that the energy generated during braking does not go to waste (Benajes et al., 2019).

- **Plug-in Hybrid Electric Vehicles (PHEVs)**

A plug-in hybrid vehicles is a car that operates using electricity provided by its batteries as well as fossil fuels such as gasoline or diesel. Vehicle owners can charge the battery in their vehicles by plugging it into a charging station (Ediz, 2017). At the same time, a system called regenerative braking helps charge the batteries by providing power to the battery every time the driver brakes. Plug-in hybrids use electricity from the battery to move the wheels, and when the batteries are depleted, the gasoline engine kicks in to provide power for movement (Singh et al., 2021). Figure 7 shows a plug-in hybrid electric vehicle.

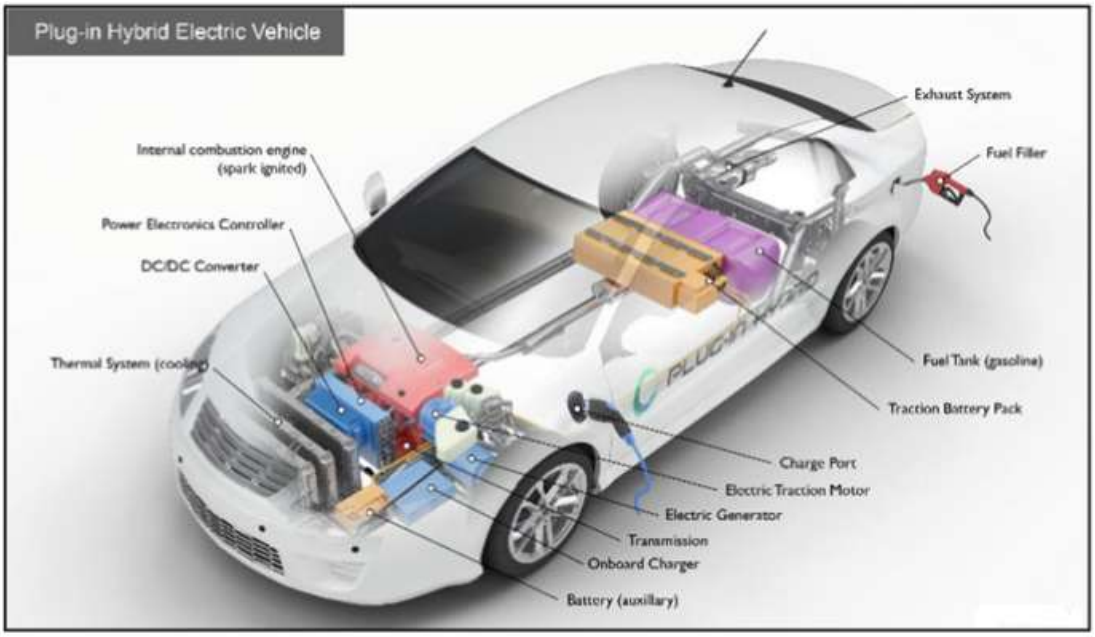


Figure 7. Plug-in hybrid electric vehicle (Singh et al., 2021)

- **Fuel Cell Electric Vehicles (FCEVs)**

In the most basic terms; it occurs as a result of the reaction of hydrogen in the fuel cell with oxygen in the air. The produced electrical energy is used to power the electric motor, similar to fully electric vehicles. As a result, only steam and hot air are emitted into the environment. Fuel cell cars can also recover energy lost during braking and store it in the battery (Arat et al. 2020). Figure 8 shows the internal structure of a fuel cell electric vehicle.

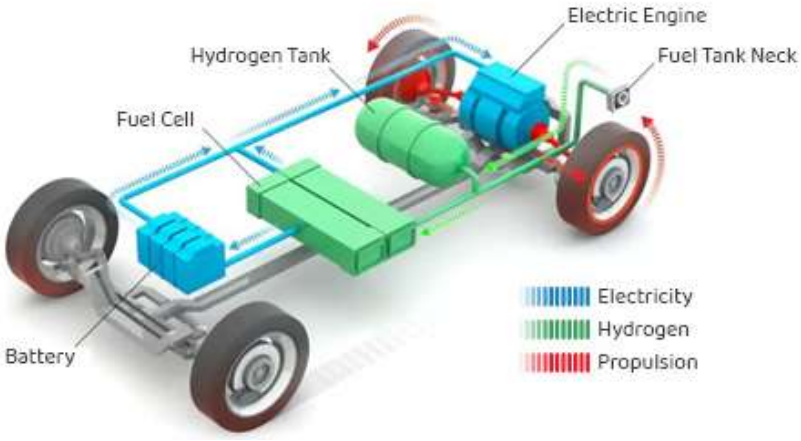


Figure 8. Fuel cell electric vehicle interior structure (Kül, 2023)

Advantages and Disadvantages of Electric Vehicles

	Advantages	Disadvantages
Electric Vehicles (EV)	➢ Zero exhaust emissions ➢ Silent operation ➢ Fast battery charging ➢ Energy recovery through regenerative braking ➢ Low fuel and operating costs	× Limited range × The need for development in battery technology × Limited infrastructure for charging stations in public areas
	Advantages	**Disadvantages**
Hybrid Electric Vehicles (HEVs) **Plug-in Hybrid Electric Vehicles (PHEVs)**	➢ Low fuel costs ➢ Low exhaust emissions due to low fuel consumption ➢ Energy recovery through regenerative braking ➢ Option to charge from the grid ➢ Performance efficiency with optimum fuel use ➢ Energy recovery through regenerative braking	× High production costs × Complexity of power transmission in two different engines × Limited access to spare parts × Higher production cost × Cost and replacement of batteries × Additional weights added by batteries and power electronics
	Advantages	**Disadvantages**
Fuel Cell Electric Vehicles (FCEVs)	➢ No dependence on petroleum ➢ Zero exhaust emissions ➢ Energy recovery with regenerative braking ➢ Higher energy efficiency compared to Iym	× Very high production costs × Challenges in hydrogen production and storage × Difficulties in the use of hydrogen as fuel × Increased safety measures due to high pressure in hydrogen usage

Standards in Electric Vehicles

The automotive and electrical standards applied by the industry not only ensure that complex components and subsystems operate as intended but also reduce the likelihood of failure after they are integrated. Vehicles are large systems composed of other smaller systems, meaning that each must work in cooperation for the larger system to function. Each requires extensive verification and validation to identify and diagnose any issues that need to be corrected. The importance of standards has created a long list of requirements that companies must meet, and many of these have been categorized according to different qualities and types of needs. The different areas where EV standards are formed include:

• Electric vehicle and performance testing

• Electrical safety and functional safety testing

• Cybersecurity and software testing

There are specific groups that develop and publish standards. Some standard organizations are national, while others are international and encompass numerous countries around the world. Each focuses on the implementation of standards in different areas that help advance the development of automotive products and systems. To convey the importance of EV standards, it will be helpful to identify specific examples (AB 134/2014, 2024; AB 168/2013, 2024).

Tests Conducted on Electric Vehicles

- **Battery Vibration Testing and Testing Standards for Electric Vehicles**

The Battery, one of the most critical components of electric vehicles, is in an important development process to meet the needs of electric vehicle manufacturers. Testing standards and procedures are also continuously being evaluated and updated.

To ensure the safety and robustness of battery technology, the battery must undergo Vibration and Shock Testing. Currently, there are three internationally recognized test standards commonly used for Vibration and Shock Testing of Batteries. These are UN 38.3, ISO 12405-1, and SA J2380. However, some vehicle manufacturers have their own testing standards (Hooper & Marco, 2014; Lang & Kjell, 2015). The battery vibration test standards for electric and hybrid vehicles are shown in Table 1.

Table 1. Battery vibration test standards for electric and hybrid vehicles (Hooper & Marco, 2014).

Standard	Type of vibration test	Frequency range (Hz)	Peak loading (swept sine wave)	Peak loading (random PSD wave)	Scope of the Standard	Vibration profile created from EV data	Test correspond to a desired vehicle life
UN38.3	Shaped swept sine wave (*X*, *Y* and *Z* axes)	7–200	8 g 50 Hz–200 Hz	N/A	Legislative	No	No
ECE R100 Vibration	Shaped swept sine wave (*Z* axis)	7–50	1.02 g 7 Hz–18 Hz	N/A	Legislative	No	No
J2380/USABC Procedure 10	Random PSD/shaped swept sine (*X*, *Y* and *Z* axes)	10–190	3 g 10 Hz–20 Hz	0.1 $(g)^2$/Hz at 10 Hz–20 Hz or 3 g from 10 to 20 Hz	Duty of care	No	Yes 100,000 miles
BS62660	Random PSD (*X*, *Y*, and *Z* axes)	10–2000	N/A	2.05 $(g)^2$/Hz at 10 Hz	Duty of care	No	No

- **Sealing Tests in Electric Vehicles**

Electric vehicles have emerged as a result of the technological era. In response to the need to create a sustainable future, engines that do not consume oil, provide fuel savings, operate

efficiently, and run silently have been designed. Electric vehicles powered by this engine and battery are increasingly preferred every day (Nişancı & Kurtuluş, 2022).

The tightness of batteries in electric vehicles should be tested according to IP67 standards. For batteries used in harsh environments, leak tightness tests can be performed at higher standards such as IP69. Since standardized parameters and methods for battery leak tests have not yet been established worldwide, the methods applied vary from manufacturer to manufacturer. Two different issues can be mentioned that affect battery leak tests and put production lines at risk. The first is the difficulty of detecting small leaks due to the large volume of batteries used in larger vehicles such as buses, and the second is the inflation of flexible parts affecting the test results. Battery leak tests can be conducted using the Differential Pressure Drop Method. The goal is to perform precise, rapid, reportable, and repeatable leak tests (Hooper & Marco, 2014).

Electric Vehicles and Hydrogen Tanks use type 4 hydrogen tanks with fuel cell vehicles. These tanks are made of composite materials from carbon fiber. The sealing of hydrogen storage tanks, which hold hydrogen at 350-700 Bar, is important considering that hydrogen is a flammable gas at high pressure. It is desired to have a maximum leakage limit of 10-2 mBar l/s. The leak tests for hydrogen tanks are performed in the industry using three different methods: Helium Vacuum Chamber, Helium Sniffer, and Pressure Drop. The helium method offers higher sensitivity and allows for leak testing to be completed in shorter durations. However, the pressure drop method, while requiring longer test times, provides cost advantages to manufacturers (Kjell & Lang, 2013).

Electric motors are also adversely affected by water, steam, and dust. Therefore, the sealing tests conducted according to IP67 standards are the minimum requirements. In situations where air cannot be applied internally, an external testing method can be used. Another advantage of this method is that it reduces the test volume. In cases where the interior of the product can be pressurized, sealing tests can be conducted using the differential pressure drop method (Castillo, 2015).

Electric Vehicles and Fuel Cells, Fuel cells consist of bipolar plates which are separated by membranes and located between two end plates. The bipolar plates have a structure with 2 cavities and a cycle. While process gases such as hydrogen and air are present in the cavity structure, the cycle contains coolant. The leak tests of these two structures must be conducted separately. The leak test of the coolant is a three-stage process: it includes a leak test that checks the transition of hydrogen to the external environment and a leak test that controls the hydrogen cooling cycle. For higher precision in the leak tests of fuel cells, the helium vacuum chamber method is preferred (Savran et al., 2024; Arat et al., 2020).

- **Safety Tests Conducted on Electric Vehicles**

Electric vehicles require a different safety standard compared to traditional internal combustion engine vehicles. The battery technology and electrical systems of electric vehicles necessitate special safety measures and testing standards. Therefore, specific tests and standards have been established for the safety of electric vehicles.

The tests conducted to ensure safety in electric vehicles include crash tests, fire tests, battery safety tests, and electrical safety tests. Crash tests are performed to ensure the safety of passengers and the vehicle in the event of a collision. These tests are carried out to evaluate the structural integrity of the vehicle and passenger safety. Fire tests are conducted to assess the resistance of the vehicle's battery system to fire. Battery systems in electric vehicles can be

sensitive to fire, which is why fire tests are of great importance. Additionally, battery safety tests are also carried out to evaluate the safety and durability of the vehicle's battery system (BM Regülasyon-78, 2024; BM Regülasyon-141, 2024).

Electrical safety tests are carried out to ensure the safety of the vehicle's electrical systems. These tests check the insulation, grounding, and isolation of the vehicle's electrical systems. Electrical safety tests are of great importance for electric vehicles due to their high voltage electrical systems. The safety standards set for electric vehicles are established by international organizations and the automotive industry. These standards are created to ensure the safety of vehicles and to guide the industry. Electric vehicle manufacturers must adhere to these standards and produce their vehicles in accordance with them (AB 134/2014, 2024; AB 134/2014, 2024; AB 3/2014, 2024).

- **Efficiency testing and analysis of electric vehicles**

The results obtained from tests conducted on automobiles under real conditions differ from those obtained on test benches. This is a common occurrence that happens frequently. It is also prevalent in driving cycle tests such as the 10-15 mode in Japan or FTP72 and FTP75 in the USA. To overcome these differences and to approach realistic driving conditions, a new standard – WLTP (Worldwide Harmonized Light Vehicles Test Procedure) – has been developed. This standard represents a more realistic procedure for evaluating not only traditional cars but also future electric vehicles such as hybrids, BEVs (Battery Electric Vehicles), PHEVs (Plug-In Hybrid Electric Vehicles), and FCEVs (Fuel Cell Electric Vehicles). The WLTP standard is more dynamic and provides results that are closer to actual road performance (Marmaratek, 2025; Balcı et al., 2023).

The key differences between the NEDC and WLTP standards are listed below:

• 30 minutes longer per test cycle

• 23.3 km longer distance instead of 11 km

• Higher speed of 131 km/h instead of 120 km/h and average speed between 34 km/h and 46.5 km/h

• Cold start

• Higher acceleration and deceleration during driving (Marmaratek, 2025)



Figure 10. DEWETRON ile otomobil testi

In addition, transitioning from 2 region (city and highway) tests to tests based on 4 regions and real driving values (low, medium, high, and extra high-speed regions) makes the results more realistic and comparable. A road test under real conditions is the best and of course the most realistic way to test. These tests become more important for evaluation during development and aim to increase efficiency and reduce costs. Road tests provide a comprehensive review of the car, including all parameters for battery management and autonomous driving, as well as the interaction of different tasks (Marmaratek, 2025; Bayrakçeken, 2019 ; Formantin, 2021).

The power consumption test table seen in Table 2 shows the differences between the two standards mentioned earlier and the real road test. The value taken from the manufacturer's data sheet (NEDC) has been compared with the value from the test bench (WLTP) and the on-road test (Marmaratek, 2025).

Table 2. Comparison of different test procedures

	Datasheet (NEDC)	Test bench (WLTP)	On-road (WLTP)
kWh/100 km	15.3	16.2	18.5

Hybrid, BEV, PHEV, and FCEV evaluation tests require highly precise measurements of all electrical and mechanical parameters. In addition, communication interfaces (e.g., CAN / CAN-FD and automotive Ethernet) are required in combination with a precise IMU (Inertial Measurement Unit) with DGPS (Differential Global Positioning System). A processor unit with a Kalman filter is also used for evaluating inertial sensors and GPS signals. Figure 9 provides an overview of some test parameters (Isermann & Wesemwier, 2019; Jin 2022).

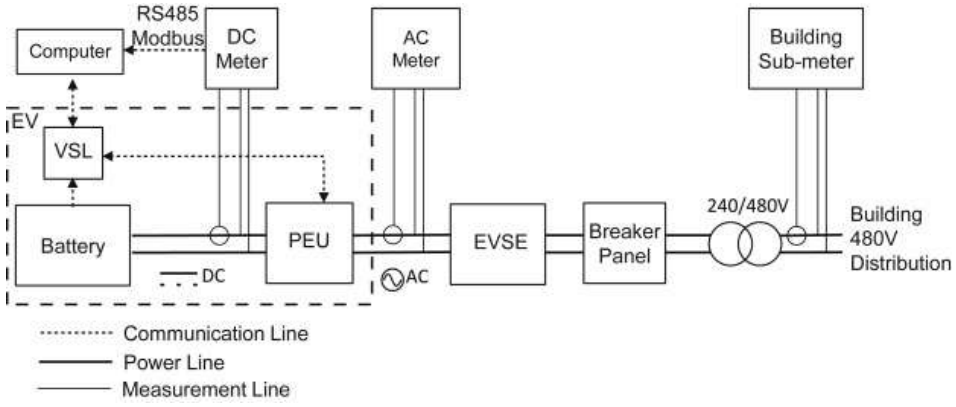


Figure 9. Example of electric vehicle measurement configuration (Apostolaki-Iosifidou, 2017)

Conclusion

According to the literature study, electric vehicles have started to be preferred over fossil fuel-powered vehicles in today's technology. Therefore, most companies are launching electric vehicle models.

As a result, specific tests and standards have been established for the safety of electric vehicles. These tests and standards ensure that the vehicles serve the environment and users safely. With the prevalence of electric vehicles, safety standards are continuously updated and improved. In

this way, electric vehicles will continue to be an environmentally friendly and safe transportation alternative. The performance of electric vehicles is measured by factors such as speed, range, and charging time. Standards ensure that vehicles have a certain level of performance. This allows users to have a satisfying driving experience and enables vehicles to compete with other transportation options.

When testing is conducted according to standards, solutions will be sought for safety issues related to the vehicle, performance and efficiency issues, problems arising from environmental impacts, and problems caused by market confusion.

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IMPACT OF DIFFERENT AMBIENT TEMPERATURES AND DISCHARGE RATES ON THE THERMAL PERFORMANCE OF A LITHIUM-ION BATTERY PACK

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ABSTRACT

This study experimentally investigates the thermal behavior of a lithium-ion battery pack subjected to varying ambient temperatures (25 °C, 35 °C, and 45 °C) and discharge rates (1C, 2C, and 3C). The battery pack was composed of nine INR18650A28 cylindrical lithium-ion cells configured in a 3S3P arrangement. T-type thermocouples were attached to the surface of each cell to monitor temperature evolution, and measurements were recorded at one-minute intervals using a data logger. Discharge tests were performed in constant current mode via a programmable electronic load within a controlled environmental chamber. The results reveal that both ambient temperature and discharge rate exert a significant influence on the pack's thermal performance. While the maximum temperature differences among cells remained below 3 °C at 1C and 2C, they exceeded 3 °C at 3C, reaching up to 4.21 °C at the highest ambient temperature. These findings underscore the necessity of an effective thermal management system to ensure uniform temperature distribution among battery cells, enhance operational safety, and prevent potential thermal runaway.

Keywords: Battery Safety, Discharge Rate, Lithium-Ion Battery, Thermal Management

Introduction

The rapid consumption of energy resources on a global scale and the increase in carbon emissions from fossil fuels have led countries towards sustainable and environmentally friendly energy solutions. In this context, electric vehicles have become one of the most important components of environmentally friendly transportation systems in line with zero emission targets (Tie & Tan, 2013; Xiao et al., 2021). At the heart of electric vehicles, lithium-ion batteries are preferred for their high energy density, long cycle life and lightweight construction. However, the safe and efficient operation of these batteries is highly dependent on the success of thermal management. High temperatures can lead not only to poor performance, but also to rapid aging, capacity loss, and even thermal runaway and explosion (Dilbaz, 2023; Selimefendigil et al., 2023).

Battery cells generate heat due to ohmic and chemical reactions that occur during charge and discharge. Especially at high discharge rates, this temperature rise can reach critical levels and cause the battery system to become unstable. In the literature, battery temperature exceeding 50 ºC has been shown to have negative effects on life and safety (Rezvanizaniani et al., 2014).

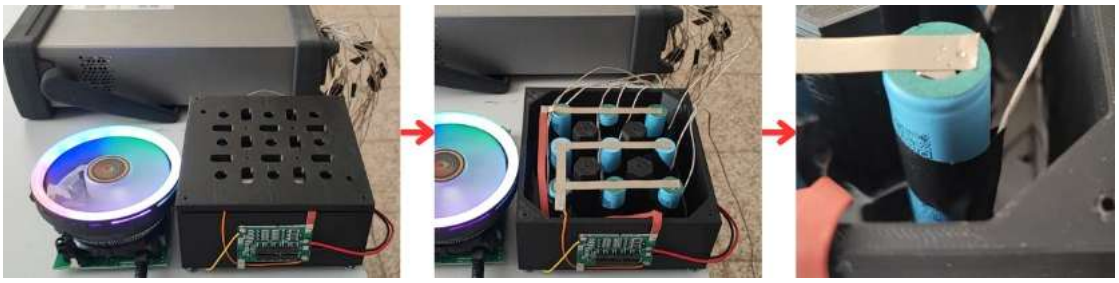
Environmental temperature is also a critical parameter in battery temperature management. Increasing the ambient temperature directly affects the maximum temperature values reached by the battery cells, increasing the overall temperature levels of the system and increasing temperature imbalances (Bao et al., 2024). Therefore, it is necessary to develop an effective heat management strategy that takes into account not only intracellular heating but also environmental conditions (Saxon et al., 2024). The uniformity of the temperature distribution within the battery groups and on the cell surfaces is of great importance. In the literature, it is stated that the temperature differences inside the battery cell or on the surface should not exceed 5 ºC (Karatas & Sokmen, 2022; Ni & Wang, 2020). The surface temperature of a lithium-ion battery cell was measured with different types and thicknesses of thermocouples (K, T and E) and the results were compared with an infrared (IR) camera. Thin wire thickness thermocouples are reported to have the fastest response time and the most accurate temperature measurement, while thick thermocouples show low temperature measurement accuracy and slow response time. As a result, T-type thermocouples are proposed as the most suitable sensors for battery surface temperature measurements (Koshkouei et al., 2024). In order to improve the safety of lithium-ion batteries at high temperatures and high discharge rates, a novel Battery Thermal Management System (BTMS) was designed and tested using liquid cooling and Phase Change Materials (PCM) in a honeycomb structure. As a result of experimental and numerical analysis, optimum cooling was achieved with the use of 12% graphite doped PCM and 25 mm cell spacing, with a maximum temperature of 45.7 ºC and a maximum temperature difference of 4.4 ºC (Yang et al., 2023).

In this study, the effects of different ambient temperatures and discharge rates on the temperature distribution within the battery pack are demonstrated with direct experimental data. Unlike the cooling system optimizations common in the literature, only the effect of environmental variables is investigated in isolation in this study. Thus, original and practical results have been obtained for the necessity of maintaining temperature uniformity in terms of battery safety.

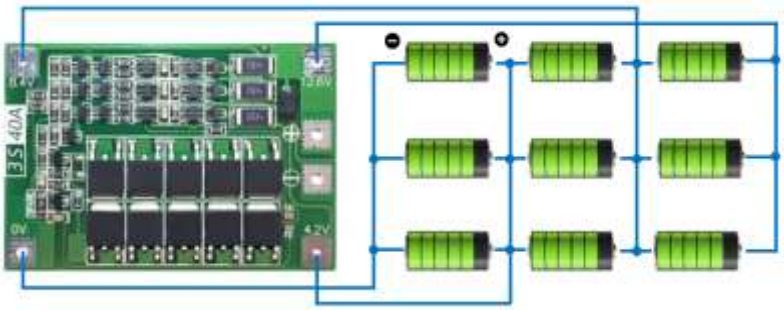
Materials and Methods

In this study, the thermal behavior of a lithium-ion battery module under different ambient temperatures (25 ºC, 35 ºC and 45 ºC) and discharge rates (1C, 2C and 3C) is experimentally investigated. The battery pack used in the experimental setup consists of a total of 9 cylindrical

lithium-ion batteries formed by 3 series 3 parallel (3S3P) connections. A real-time photograph of the experimental setup and the connection diagram of the Battery Management System (BMS) and lithium-ion battery cells are shown in Figure 1. Technical specifications of the batteries are given in Table 1. A T-type thermocouple was installed to measure the surface temperature of each battery cell and the ambient temperature was monitored with an additional thermocouple. All temperature data were recorded at 1-minute intervals with a Keysight data logger. In order to analyze the thermal behavior of the battery module, discharge experiments were performed in constant current mode at 1C, 2C and 3C rates. The discharge processes were controlled by DLP24P programmable electronic load device and their effects on temperature distributions were evaluated.



(a)



(b)

Figure 1. (a) Real-time photograph of the experimental setup (b) The schematic of the BMS and battery cell connections

Table 1. Technical specifications of the lithium-ion battery.

Process	Parameter	Value
Charge	Standard Charge Current	1400 mA
	Max. continuous discharge current	400 mA
	End voltage	4.2 V
	Cut-off current	140 mA
Discharge	Standard Discharge Current	560 mA
	Max. continuous discharge current	14000 mA
	Max. conditional discharge current	25000 mA
	(SOC>70% cut-off temperature 80 ºC)	
	End voltage	2.5 V
Operating Temperature	Charge	0 ºC / 60 ºC
(Cut-off temperature 80ºC)		
	Discharge	-30 ºC / 60 ºC

Findings and Discussion

The average surface temperature changes of the lithium-ion battery pack at different discharge rates (1C, 2C and 3C) under different ambient temperatures are shown in Figure 2. In Figure 2 (a), at 25 ºC ambient temperature, the maximum temperatures at 1C, 2C and 3C discharge rates were recorded as 29.01 ºC, 37.20 ºC and 45.01 ºC, respectively. In Figure 2 (b), at 35 ºC ambient temperature, the maximum temperatures measured at the same discharge rates were 39.44 ºC, 46.72 ºC and 54.73 ºC. In Figure 2 (c), at 45 ºC ambient temperature, the maximum temperatures of the battery group were 49.36 ºC, 56.57 ºC and 64.58 ºC. These results show that both ambient temperature and discharge rate have significant effects on the thermal behavior of the battery pack. In particular, the combination of high ambient temperatures and high discharge rates leads to critical temperature increases that can threaten battery safety.

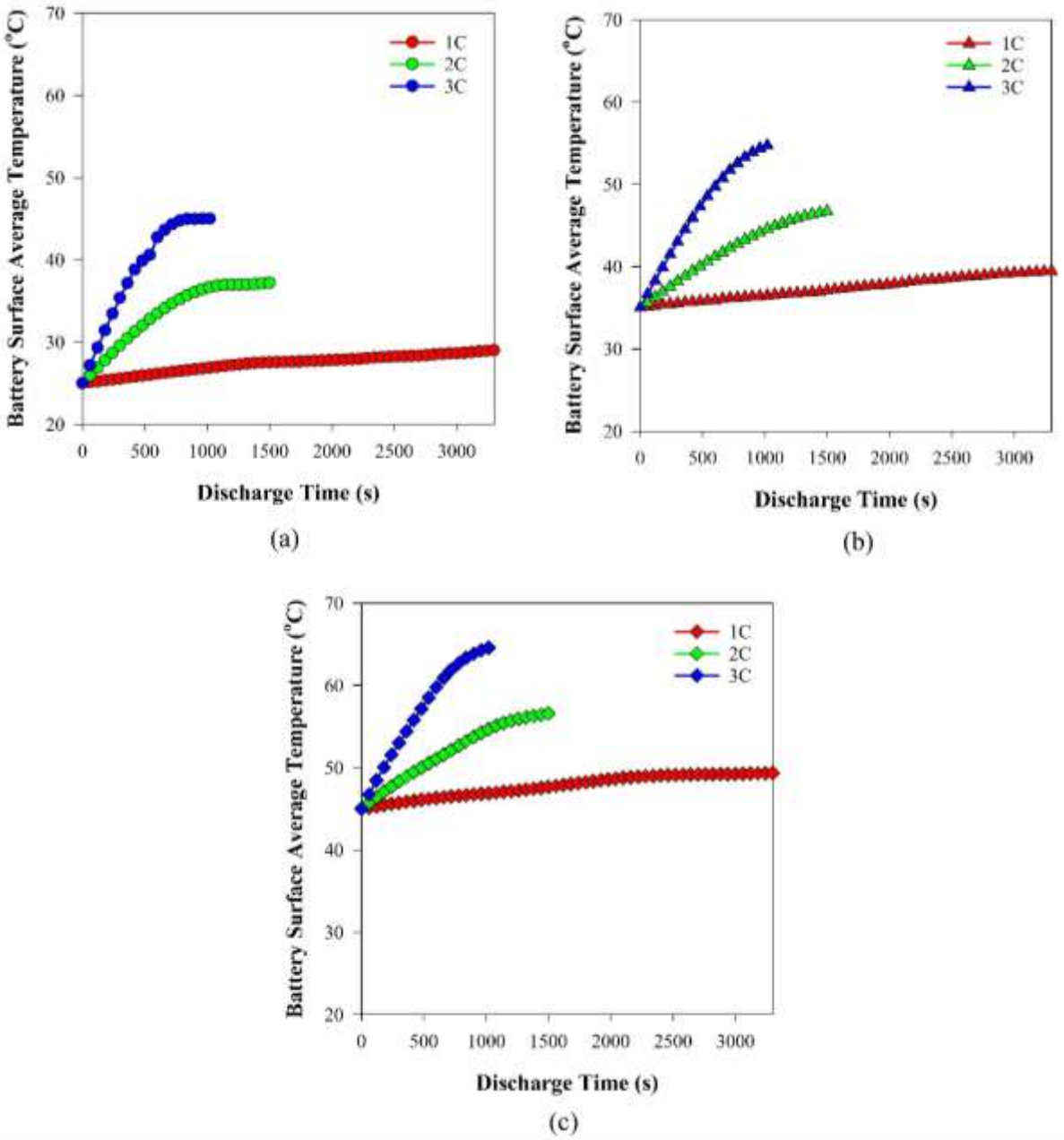


Figure 2. Change in the average surface temperature of the battery pack at different ambient temperatures and different discharge rates (a) 25 ºC, (b) 35 ºC and (c) 45 ºC

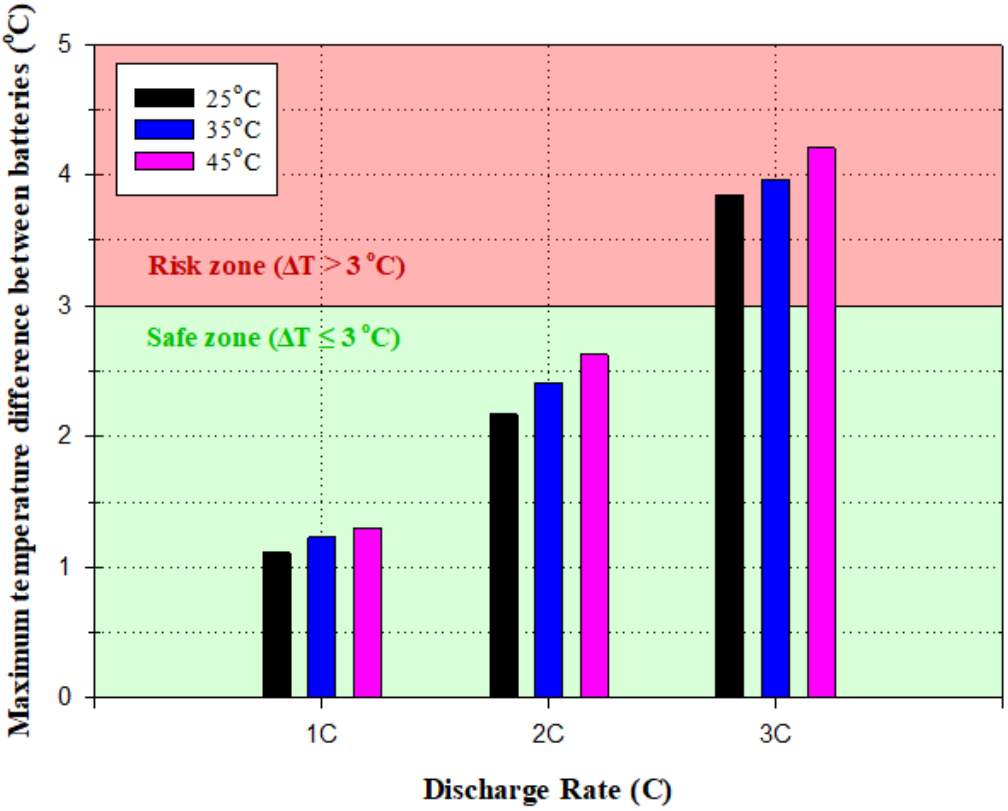


Figure 3. Effect of ambient temperature and discharge rate on the maximum temperature difference between lithium-ion battery cells

Figure 3 shows the variation of the maximum temperature difference between the cells in a lithium-ion battery pack depending on different ambient temperatures and discharge rates. According to the literature, the temperature difference between the battery cells in battery packs should not exceed 5 °C. However, in order to increase battery life and performance, it is recommended to keep this difference at 3 °C or lower. Accordingly, in this study, the area with a temperature difference of 3 °C or less was defined as a safe area and above 3 °C was defined as a risky area. Since the temperature difference did not exceed 5 °C under any circumstances, a separate hazardous zone was not required. According to the results of the experiment: At a discharge rate of 1C, at all ambient temperatures (25 °C, 35 °C and 45 °C), the temperature difference remained in the range of 1.11-1.30 °C and remained within the safe zone. At 2C discharge rate, the temperature difference was measured between 2.17-2.63 °C and a slight upward trend in the temperature difference was observed due to the increase in the ambient temperature. At 3C discharge rate, the temperature difference increased significantly and moved into the risk zone. At ambient temperatures of 25 °C, 35 °C and 45 °C, temperature differences of 3.85 °C, 3.96 °C and 4.21 °C were recorded, respectively. These findings suggest that under a discharge rate of 3C, a temperature imbalance occurs between the cells regardless of the ambient temperature, which may increase the risk of thermal runaway when high discharge rate and high ambient temperature are combined.

Conclusion and Recommendations

In this study, the thermal behavior of a lithium-ion battery pack under varying ambient temperatures and discharge rates was experimentally analyzed. A 3S3P configured battery pack was subjected to different thermal and electrical conditions, and temperature distribution among the cells was closely monitored. The main findings obtained from the study are summarized as follows:

- At 1C discharge rates, the maximum temperature differences between battery cells remained within 1.11–1.30 °C across all ambient temperatures.
- For a 2C discharge rate, slight increases in temperature differences were noted, but all values stayed below 3 °C, which is acceptable for battery performance and safety.
- At 3C discharge rates, the maximum temperature differences exceeded 3 °C, reaching 3.85 °C at 25 °C ambient, 3.96 °C at 35 °C ambient, and 4.21 °C at 45 °C ambient, indicating increased thermal imbalance risks.
- The combination of high ambient temperature and high discharge rate negatively affected the thermal distribution within the battery pack, potentially increasing the risk of thermal runaway.
- Effective thermal management strategies are essential, particularly under extreme operating conditions, to ensure cell temperature uniformity and prevent performance degradation and safety hazards.

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SMART ROBOTIC END EFFECTOR WITH PNEUMATIC ACTUATION AND HUMAN DETECTION FOR INDUSTRIAL SAFETY

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ABSTRACT

This study presents the development of a safety-oriented robotic end effector that integrates pneumatic actuation with computer vision technologies for use in industrial automation environments. The motivation behind the project lies in minimizing occupational hazards by enabling robotic end effectors to autonomously detect and respond to potential human presence in their workspace. By doing so, the system aims to halt operations in unsafe conditions and resume seamlessly when the area is cleared, thereby reducing the risk of injury without compromising productivity. The system utilizes an ESP32 microcontroller and an OV2640 camera module to implement image-based human detection, specifically focusing on identifying hands or fingers. Once detected within the operational range, the robot's pneumatic mechanism instantly ceases movement, prioritizing safety. Upon clearance, it automatically resumes its task. Pneumatics was chosen for its inherent advantages—fast response, precise control, and energy efficiency—making it highly suitable for high-cycle industrial applications. This solution is not only cost-effective but also modular and adaptable, offering scalability for future integration with AI-driven decision-making algorithms and additional sensors. Its compatibility with Industry 4.0 standards and smart manufacturing paradigms positions it as a forward-looking innovation that addresses both safety and efficiency in collaborative human-machine settings. The proposed system reflects a novel engineering approach, emphasizing preventive safety through real-time environmental awareness and intelligent control strategies.

Keywords: End Effecor, Image Processing, Pneumatics

Introduction

In recent years, the rapid progression of robotics and automation technologies has profoundly transformed industries such as manufacturing, logistics, healthcare, agriculture, and even domestic environments, leading to unprecedented improvements in productivity, accuracy, and operational efficiency. As these automated systems and robots increasingly operate alongside humans in shared workspaces, the importance of ensuring occupational safety and accident prevention has become a critical aspect of industrial design and operational management. Traditional safety measures, including physical barriers, safety cages, emergency stop buttons, and light curtains, although proven effective, often introduce significant limitations such as reduced flexibility, decreased workspace utilization, increased installation and maintenance costs, and reduced overall productivity due to rigid operational constraints. These limitations have spurred the development of more advanced, intelligent safety systems that can dynamically monitor human presence and activity in real-time, enabling robots to adapt their behavior instantaneously to prevent potential accidents. The advent of computer vision technologies, which leverage high-resolution cameras, image processing algorithms, and machine learning techniques, has opened up new possibilities for creating sophisticated human detection systems that are more flexible, accurate, and responsive. These systems can identify human features, gestures, postures, and movements, providing essential contextual information that allows robotic systems to operate more collaboratively and safely in unstructured or semi-structured environments. Integration of sensors and microcontrollers such as the ESP32, combined with embedded cameras and pneumatic actuation mechanisms, further enhances these safety systems by enabling rapid detection and immediate physical response—such as halting robot motion, activating safety barriers, or triggering alarms—without reliance on bulky infrastructure or manual controls. Such integrated solutions are particularly vital in collaborative robotics (cobots), where humans and robots work in close proximity, often sharing the same workspace, necessitating highly reliable, real-time safety protocols that do not impede workflow or productivity.

Despite the promising advancements in this field, several significant challenges remain. One of the primary issues is achieving high detection accuracy under diverse environmental conditions, including varying lighting, shadows, occlusions, cluttered backgrounds, and dynamic human movements. False positives—where the system incorrectly identifies a human or perceives a non-threatening object as a human—can lead to unnecessary halts or operational delays, reducing efficiency and potentially causing safety fatigue or complacency. Conversely, false negatives—missed detections—pose serious safety risks, as they fail to prevent potential accidents. Furthermore, latency in detection and response, especially in fast-moving industrial environments, can be critical; any delay between human detection and system response could result in injuries or equipment damage. Cost considerations also play a vital role, as many advanced safety systems require sophisticated sensors and high-end processing units, which may be prohibitive for small- and medium-sized enterprises. Therefore, designing a cost-effective, scalable, and easy-to-integrate safety solution remains a key goal.

This research aims to address these multifaceted challenges by developing an integrated, intelligent safety system that combines state-of-the-art computer vision techniques, microcontroller-based control modules such as the ESP32, and pneumatic actuation mechanisms for rapid physical response. The core objective is to create a reliable, real-time human detection system capable of functioning efficiently under different environmental conditions, minimizing false alarms while maximizing detection accuracy and response speed. The system design emphasizes affordability and simplicity to facilitate widespread adoption

across various industrial sectors, including manufacturing lines, warehouses, hospitals, and collaborative robotic setups. By integrating these components, the system can automatically detect human presence within a designated safety zone, trigger immediate halting of robotic operations, activate safety barriers, or initiate other protective actions, thereby significantly reducing the risk of accidents and injuries. Such an approach not only enhances safety standards but also promotes greater confidence in automation and human-robot collaboration, encouraging broader implementation of intelligent safety protocols that are adaptable, responsive, and cost-effective.

Moreover, this study seeks to explore the potential for further innovations, such as integrating additional sensors (e.g., ultrasonic, infrared), employing advanced machine learning algorithms for better recognition under challenging conditions, and developing adaptive response strategies that consider the context and proximity of detected humans. It also aims to evaluate the system's performance through extensive testing in real-world industrial environments to ensure robustness, reliability, and compliance with safety regulations. Ultimately, the goal is to contribute meaningful advancements to the field of industrial safety, fostering safer, more efficient, and more harmonious human-robot interactions, and laying the groundwork for future developments that will enable smarter, more adaptable safety systems capable of meeting the evolving demands of modern industry. This comprehensive approach seeks not only to mitigate current safety challenges but also to pave the way for innovative, integrated solutions that enhance the overall safety culture in automation-driven workplaces, ensuring that technological progress benefits both workers and enterprises alike.

Materials and Methods

The development of the safety-oriented robotic end effector involved the selection and integration of several key components designed to work synergistically to achieve reliable human detection and rapid response. The primary hardware includes an ESP32 microcontroller, renowned for its high processing capability, low power consumption, and built-in Wi-Fi and Bluetooth connectivity, making it suitable for real-time control and communication in industrial environments. Attached to the ESP32 is the OV2640 camera module, which provides high-resolution image acquisition necessary for accurate human feature detection. To facilitate rapid and effective actuation upon detection, pneumatic systems were chosen due to their quick response times, energy efficiency, and ease of control. The pneumatic setup comprises a compact compressor, a series of solenoid valves, and pneumatic cylinders that serve as the physical mechanism to halt or modify the robot's movement when necessary. The control signals generated by the ESP32 are sent to the solenoid valves, which in turn control the flow of compressed air to the pneumatic cylinders, enabling immediate intervention. The image processing pipeline begins with the acquisition of real-time images through the OV2640 module, which are then pre-processed to enhance detection accuracy. Pre-processing steps include noise reduction, contrast adjustment, and normalization. For human detection, a custom-trained lightweight machine learning model based on convolutional neural networks (CNN) is employed, optimized for embedded systems to balance accuracy and computational load. Alternatively, traditional image processing techniques such as color segmentation, skin-tone detection, and contour analysis can be utilized for environments with controlled lighting conditions. Once a human hand or finger is detected within a predefined safety zone—an area established relative to the robot’s operational workspace—the system immediately triggers an emergency stop sequence. The real-time detection and response cycle are designed to operate within milliseconds, ensuring safety without significant delay. The system architecture emphasizes modularity and scalability. The ESP32 microcontroller interfaces with the vision

system, pneumatic controls, and communication modules via standard protocols such as UART, I2C, or Wi-Fi. This design allows easy integration with existing industrial control systems or future expansion to include additional sensors like LIDAR, ultrasonic sensors, or infrared detectors for enhanced environmental awareness. Safety logic algorithms are implemented in embedded C, enabling fast decision-making processes, while the entire setup is housed within a rugged enclosure suitable for industrial conditions. Power supplies are carefully selected to ensure stable operation, with backup power options considered for critical safety functions. The experimental setup involves mounting the system on a robotic arm or workstation, with safety zones clearly marked, and human subjects performing predefined movements to test detection accuracy, response times, and overall reliability under various lighting and background conditions. Data logging and analysis tools are employed throughout testing to evaluate system performance, identify failure modes, and optimize detection thresholds.

Findings and Discussion

Experimental tests demonstrated that the integrated vision and pneumatic safety system effectively detected human presence within the workspace, halting robot movements within milliseconds to prevent potential injuries. The system achieved a high detection accuracy under controlled conditions, alerting and stopping operations promptly when a human hand or finger was within the safety zone. The pneumatic actuation provided a reliable and rapid response, essential in high-speed industrial processes. Moreover, the modular architecture facilitates scalability, enabling future incorporation of AI-based decision-making algorithms, additional sensors, and communication modules compliant with Industry 4.0 standards. The approach offers a significant safety improvement over traditional methods, reducing the risk of accidents without interrupting the overall workflow. However, some limitations were observed, including sensitivity to environmental factors such as lighting variations and background complexity, which may affect detection accuracy. Therefore, further research is recommended to enhance the robustness of the image processing algorithms and validate system performance in diverse industrial scenarios.

Conclusion and Recommendations

In conclusion, this study successfully demonstrates the feasibility and effectiveness of integrating computer vision, microcontroller-based control, and pneumatic actuation to enhance occupational safety in robotic working environments. The developed system offers a rapid, reliable, and cost-efficient solution for real-time human detection and immediate response, thereby significantly reducing the risk of accidents and promoting safer collaboration between humans and robots. The experimental results indicate that the system can detect human presence accurately within milliseconds, respond swiftly through pneumatic intervention, and operate effectively under different environmental conditions, showcasing its robustness and adaptability. However, despite these promising outcomes, several limitations have been identified that warrant further research and development. These include potential challenges in dynamic or cluttered environments where false detections might occur, the need for more advanced machine learning models to improve detection accuracy, and considerations related to system scalability and integration with existing industrial infrastructure. To maximize the system’s potential and facilitate wider adoption, future studies should focus on incorporating more sophisticated sensor fusion techniques, such as combining vision with ultrasonic or infrared sensors, to enhance detection reliability. Additionally, developing adaptive algorithms capable of learning and adjusting to changing environmental conditions can further improve performance. A focus on miniaturization and power optimization will also be beneficial for deploying the system in diverse industrial settings. Moreover, establishing standardized safety

protocols and conducting long-term field testing are essential to validate the system's effectiveness in real-world scenarios and ensure compliance with safety regulations. Future work could explore the integration of IoT frameworks for remote monitoring and diagnostics, enabling predictive maintenance and continuous safety assurance. Finally, collaborations with industry stakeholders and regulatory bodies are recommended to facilitate the transition from prototype to commercial deployment, ensuring that such safety systems can be reliably implemented at scale to foster safer, more productive, and more intelligent manufacturing environments.

Thanks and Information Note

We extend our heartfelt and sincere gratitude to all team members, industry partners, research collaborators, and supporting institutions whose unwavering dedication, expertise, and resources have been instrumental in the successful execution and progression of this project. Their valuable contributions, insightful feedback, and collaborative spirit have significantly enriched the research process and outcomes. We also wish to acknowledge the essential role played by our industrial partners, whose real-world insights and practical support have helped us tailor our solutions to meet actual operational needs and challenges faced in various industrial environments. Furthermore, we recognize the importance of the support provided by research and academic institutions that facilitated access to essential tools, facilities, and knowledge resources, thereby enabling us to carry out in-depth investigations and comprehensive testing. Our sincere thanks extend to the funding agencies and governmental bodies that recognized the importance of this research and provided financial support, ensuring the continuity and depth of our study.

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BENDING MACHINE CONTROLLED FROM MOBILE APPLICATION

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ABSTRACT

Within the scope of this project, a compact, table-type pneumatic bending machine has been developed to ensure the precise and repeatable bending of sheet metal.The system produces mechanical movement through pneumatic cylinders and performs controlled bending operations.All operations can be remotely controlled via a user-friendly mobile application that works over Bluetooth communication.The machine body is manufactured from high-strength steel alloys, providing structural rigidity and long-lasting use.Its compact dimensions enhance the device's portability and allow for quick adaptation to different production environments.In the pneumatic system, low-pressure air inlets have been used, and all flow control is secured with high-precision valves and pressure regulators.Thus, the system operates safely and maintains consistent performance in every cycle.To increase the precision of the bending process, the stroke movement of the pneumatic cylinder has been supported by specially designed molds and fixtures.Therefore, optimal process repeatability has been achieved for different material thicknesses.The control system has been developed to work in harmony with Android and iOS-based mobile devices, allowing users to manage the machine remotely and in real-time.The system interface allows for the adjustment of operational parameters and the monitoring of process steps.The developed machine offers a wide range of applications, from industrial production environments to small-scale workshops and prototyping efforts, demonstrating high performance in terms of both efficiency and ease of use.

Keywords: pneumatic, mobile application, flow control, portable

Introduction

The primary objective of this project is to develop a compact, desktop-sized pneumatic bending machine that can be remotely controlled via a mobile application. The aim is to provide a space-efficient, user-friendly, and digitally controlled system that offers an economical, portable, and efficient solution suitable for both industrial and small-scale production environments—standing as an alternative to traditional bending machines.

Within the scope of the project:

-Precise and repeatable bending of sheet metal is achieved,

-Real-time remote control of the system is made possible through a Bluetooth-connected mobile application,

-The use of high-precision valves and dies enhances technical accuracy and operational safety during production processes.

As a result, users can manage production operations more quickly, safely, and flexibly. Furthermore, due to its compact design, the system can be conveniently utilized in prototyping applications, educational laboratories, and workshops with limited space.

Materials and Methods

Below is a list of the main materials and components used in the development of the compact pneumatic bending machine controlled via a mobile application:

1. **Mechanical Structure and Frame Materials**

High-strength steel alloys:

Used for the machine frame and supporting structures to ensure durability and rigidity.

Aluminum profiles (optional):

Preferred in some supporting parts for their lightness and ease of assembly.

Fasteners (screws, nuts, bolts, washers):

Used for assembling and mounting various parts.

2. **Pneumatic Components**

Pneumatic cylinder:

Generates mechanical motion to perform the bending operation.

Solenoid valve:

Used to direct the airflow and control the cylinder.

Pressure regulator:

Reduces and stabilizes the incoming air pressure to the desired level.

Flow control valves:

Used to adjust the movement speed of the cylinder.

Air filters and lubricators (FRL unit):

Provide clean and lubricated air to the pneumatic system.

Pneumatic hoses and connectors:

Enable air transmission within the system.

3. **Electronic and Control Components**

ESP32 microcontroller board:

Enables Bluetooth communication with the mobile application and controls the valves.

Relay module:

Used to control pneumatic valves with the low-power outputs of the ESP32.

Power supply (12V adapter or battery):

Provides the required electrical power for the system.

Button and emergency stop switch:

Installed as a safety measure.

4. **Software and Mobile Application Components**

Mobile application (Android/iOS):

Allows users to start, stop, and configure bending operations through a user interface.

Bluetooth communication module (integrated in ESP32):

Enables wireless communication with the mobile device.

Arduino IDE / PlatformIO:

Used to develop the software for the ESP32 microcontroller.

5. Dies and Fixtures

Bending dies and fixtures (steel):

Specially designed parts that ensure precise and stable bending of the sheet metal.

Findings and Discussion

Successful Compact Design:

The developed pneumatic bending machine is designed in compact, desktop-friendly dimensions. This makes it suitable for use in small workshops and prototype production areas.

Precise and Repeatable Bending Operation:

Thanks to the pneumatic system and custom molds, high accuracy and repeatability have been achieved in bending operations performed on materials of different thicknesses. Measurement results have shown that the desired bending angles are achieved within a ±1° tolerance.

Mobile Application Controlled Operation:

Through a Bluetooth-based mobile application, remote control of the device and real-time parameter adjustments have been seamlessly provided. The functionality and simplicity of the user interface were positively evaluated in terms of user experience.

Pneumatic System Performance:

Low-pressure air inputs and the use of precise regulators ensured safe and stable system operation. Smooth and controllable speeds were achieved in cylinder movements.

Conclusion and Recommendations

The compact pneumatic bending machine developed within the scope of this project offers a precise, repeatable, and safe bending solution with the ability to be remotely controlled via a mobile application. Thanks to the high accuracy and stability of the pneumatic system, sheets of varying thicknesses have been successfully bent. Its compact and portable design has emerged as an ideal alternative for small-scale production workshops and educational environments. Additionally, the user-friendly mobile application has enhanced flexibility and efficiency by allowing easy management of process parameters. Overall, the project has achieved success both technically and economically, demonstrating the positive contributions of integrating pneumatic and digital control technologies into production processes.

Sensor Integration:

By integrating sensors (e.g., potentiometers, force sensors) for real-time measurement of parameters such as bending angle and force, the control system can be made more precise and automated.

Data Recording and Analysis:

Cloud-based or local database solutions can be developed for recording and analyzing process data. This allows for monitoring and improving production quality.

Multi-Axis Bending:

By expanding the system with pneumatic cylinders that move along different axes, more complex bending operations can be performed.

Energy Efficiency:

Methods for air recovery and pressure optimization can be researched for energy savings in the pneumatic system.

Industrial Integration:

The machine can be developed to support industrial communication protocols (Modbus, OPC-UA, etc.) for integration with factory automation systems.

Mobile Application Development:

To enhance user experience, graphical bending programs, training modules, and fault diagnosis features can be added to the application.

Thanks and Information Note

This project aims to develop a compact and portable pneumatic bending machine that can be controlled via a mobile application. In the prototype stage, the technical specifications, mechanical structure, pneumatic circuit, and control software of the system have been successfully designed and implemented. The results obtained have shown that the device can

perform precise and repeatable bending operations in different production environments. The remote control capability provided by the mobile application has increased ease of use and efficiency. The project offers a suitable solution for a wide range of applications, from small-scale workshops to industrial production..

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This innovative project on a mobile-controlled pneumatic bending machine highlights the integration of pneumatic, electronic, and software components to achieve precise, safe, and portable sheet metal bending, suitable for various industrial and educational applications. The system's design emphasizes portability, user-friendliness, and high accuracy, with potential enhancements such as sensor integration, data analysis, multi-axis bending, and industrial communication protocols to expand functionality and efficiency. For further reading, relevant sources include J. Smith et al., "Pneumatic Systems in Manufacturing," International Journal of Mechanical Engineering, 2020; A. Johnson, "Mobile Automation in Small-Scale Manufacturing," Automation in Industry, 2019; and K. Lee, "Advances in Pneumatic Actuators," Journal of Automation Technology, 2021.

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USE AND BENEFITS OF FIBEROPTIC VIBRATION SENSORS IN BATTERY MANAGEMENT SYSTEMS IN MILITARY BATTERIES

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ABSTRACT

Numerous physical factors influence a battery, among which temperature, voltage, and vibration are currently the most significant. Circuit arrangements called battery management systems (BMS) have been developed over the last few years to track the physical changes occurring in the battery. BMS is vital in extending the battery's life and protecting its health. This technological advancement of the battery has also influenced the defense industry and military vehicles. The study examined the advantages of using Fiber optic sensors in BMSs for safer, less prone to harsh environments, and longer-duration management for military vehicle batteries in extreme environments. It is seen that the use of Fiber optic vibration sensors in the explained battery management system is beneficial in terms of non-interference of the battery by external magnetic fields, lighter structure, being quicker than Fiber sensors since data transmission occurs with the help of light, and in measurement parameters like high accuracy and sensitivity. Such a BMS structure has been simulated with the help of Arduino or any microprocessor. Weight reading can also be taken for different battery life predictions. Based on the literature review, no direct research has been done on a fiber optic-based BMS structure in vibration measurements for military batteries. However, it was mentioned that the Fiber optic-based vibration sensor has significant advantages in military applications with its lightweight, low cost, and high sensitivity measurement. It is hoped that the result of this study will be significant in the creation of intelligent battery systems for future use in the defense sector.

Keywords: Battery management system, fiber optic sensor, military batteries, real-time monitoring, vibration detection

Introduction

The stable, reliable, and high-efficiency operation of energy storage units is critical for maintaining state-of-the-art defense systems. Batteries in military platforms are exposed to various stress factors, including temperature, humidity, impact, and vibration. Therefore, it is crucial to monitor the current status and performance of the battery. Battery Management Systems (BMS) are basic control units that address this need (Yılmaz et al., 2024). BMSs are essential for prolonging battery lifespan and maintaining health. This technological advancement in battery systems has impacted the defense industry and military vehicles (Üçgün et al., 2021). BMSs are integrated control systems that continuously monitor and manage basic battery parameters to ensure energy storage units' safe, efficient, and long-lasting operation (Kıvanç, 2019). They provide real-time information about the battery's current status by monitoring critical data such as voltage, temperature, and state of charge (SoC) (Ranawat & Prasad, 2018). They also transmit this data to users or upper-level control units, enabling timely action against potential overvoltage, temperature increases, or unbalanced charge/discharge conditions. Thus, the BMS increases operational safety and optimizes battery life (Aktaş et al., 2020).

A battery pack is a structure formed by assembling multiple battery cells in a specific configuration. These packs are formed by configuring the cells in series or parallel to provide the required voltage and current levels for the application. Battery cells connected in series determine the total output voltage, while those connected in parallel increase the total current capacity and energy density the system provides. In these configurations, imbalances between cells can negatively affect voltage or temperature differences. This is where BMS comes into play, ensuring these different connections' coordinated and safe operation (Akgündoğdu et al., 2017).

As a result of research conducted in the late 1990s, the basic functions that a battery management system (BMS) should have can be classified as follows: data collection, determination of battery status (i.e., charge status), electrical management, thermal management, and security management. Figure 1 (Jossen et al., 1999) shows BMS sub-components.

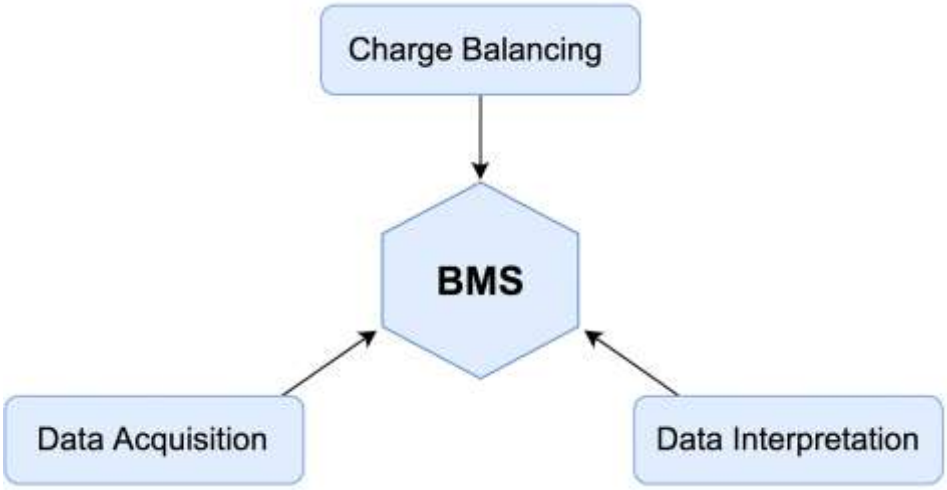


Figure 1. BMS Architecture

The data collection function allows the battery system and basic parameters related to the vehicle's power system to be continuously monitored and recorded through various sensors.

This function enables the measurement of many parameters, such as the input and output current of the battery, voltage values based on the battery pack and cells, and battery and ambient temperatures, in real time.

Determining the battery status involves calculating fundamental indicators that show the battery's current performance, lifespan, and operational adequacy. In this context, the battery system's status is expressed through critical parameters such as state of charge (SoC), state of health (SoH), state of energy (SoE), and remaining useful life (RUL). Accurately estimating these parameters significantly improves the BMS's decision-making processes and directly impacts the safety and efficiency of battery use (Piller et al., 2001).

The battery safety management function aims to ensure system safety by preventing electrical and physical limit values from exceeding during battery operation. One of the basic components of this function is the continuous monitoring of the depth of discharge. Deep discharge occurs when a large portion of the battery's capacity is used. This can lead to negative consequences, such as capacity loss, cell imbalance, and irreversible damage in the long term (Karadağ & Dikmen, 2021).

Fiber optic (FO) sensor technologies are gaining more and more attention for integration into BMS circuits. These sensors offer several technical and physical advantages over traditional electrical sensors, particularly for vehicles and systems operating in harsh environments. FO sensors offer several key advantages, including high immunity to electromagnetic interference, high sensitivity, wide temperature resistance, chemical stability, small size, and flexible structure (Corbellini et al., 2012).

Fiber optic (FO) sensors can precisely monitor parameters such as temperature, voltage, pressure, strain, and vibration thanks to their features. This increases battery cells' operational safety and performance efficiency (Bao & Chen, 2012). First, fiber Bragg grating (FBG)-based sensors offer high resolution and signal stability in multi-parameter detection because they can perform wavelength-based measurements. Additionally, these sensors can be directly integrated into battery cells due to their small size, providing cell-based monitoring and facilitating the early detection of imbalances between cells (Hill & Meltz, 1997).

The passive structure of fiber optic (FO) sensors means they do not require an external energy source. This makes them ideal for military applications with sensitive security and limited energy access. Additionally, the fiber lines used for signal transmission in these sensors can carry data with minimal loss over long distances, enabling high accuracy and the timely transfer of information to central control units (Kersey et al., 1997).

Materials and Methods

The experimental system developed in this study is based on a prototype of a microcontroller-powered battery management system (BMS). The Arduino platform was chosen for the hardware infrastructure. The system uses sensors based on the piezoelectric principle and a fiber Bragg grating (FBG)-based fiber optic sensor to detect vibrations. In the experimental setup, battery samples with different levels of aging — one unused, one used and worn out, and one at the end of its life — are placed on a vibrating surface. The relevant sensors are integrated with physical contact to the surface of each battery. The vibration data obtained through the sensors is monitored in real time in the Arduino IDE environment, and the goal is to record it simultaneously using the SD card module.

The system processes analog signals from sensors mounted on the battery's surface by converting them into digital data with the Arduino's ADC (analog-to-digital converter) unit. The real-time data obtained is analyzed to determine if the vibration level is related to the battery's health. If the threshold value is exceeded, the system disconnects the load circuit, puts the battery into protection mode, or warns the user. The system is designed to be lightweight, portable, low-power, and long-lasting in military field conditions for military vehicles. The Arduino code for the BMS circuit, created with the help of a fiber optic vibration sensor, is shown below.

Thanks to their basic advantages, such as electromagnetic field immunity, high sensitivity, bandwidth, chemical inertness, and compact design, FO sensors offer more reliable detection solutions, especially in military and industrial areas with intense electromagnetic interference. Additionally, FO sensors can accurately measure physical parameters such as temperature, strain, and vibration thanks to their sensitivity to changes in light wavelength. Their structure without metallic components also makes them safer in high-voltage systems, providing a positive advantage for use in sensitive areas, such as explosive environments or weapon systems. Their miniature, flexible structures allow them to be easily placed in narrow spaces like battery cells. This feature significantly increases the operational efficiency of directly observing intra-cell parameters.

However, the fragile nature of the sensors sometimes requires physical protection in environments with vibration or impact. Despite this limitation, their compact, passive structure makes them stand out in terms of low maintenance and energy consumption over the long term.

This study developed a vibration monitoring system to detect potential hazards caused by vibration and increase battery safety. The system is based on an Arduino microcontroller platform that continuously monitors analog data obtained from the fiber Bragg grating (FBG) sensor output. When vibration intensity exceeds a predetermined threshold, the system automatically disconnects the battery load from the circuit and alerts the user with a visual warning. Additionally, sensor data is recorded in real time on an SD card for long-term monitoring and analysis. This structure protects the battery system against vibration-induced failures and stores the obtained data for further analysis. The code fragment developed in this context is shown in Figure 2.

Findings and Discussion

During testing, it was observed and recorded that the vibration signals detected in worn and expired batteries had a higher amplitude and were irregular. Therefore, we can conclude that internal structural deterioration increases vibration sensitivity. The high sensitivity of fiber optic sensors enables the BMS's failure prediction and protection algorithms to work more effectively. In particular, the electromagnetic immunity and miniaturization of fiber Bragg grating (FBG) sensors increase the system's adaptability to the field.

Conclusion and Recommendations

The fiber optic vibration sensor supported by the BMS developed within the scope of this study provides an effective monitoring and protection solution for military batteries, especially those operating in harsh environmental conditions. Experimental applications revealed that vibration data from batteries at various stages of aging directly correlates with battery health. In this context, high-amplitude and irregular vibration signals were especially prevalent in worn and

exhausted batteries. These results demonstrate that the system can play a critical role in preventive maintenance planning and the early diagnosis of sudden failures.

The electromagnetic immunity, high sensitivity, and compact design of fiber optic sensors facilitate integration into military applications. The system's low cost, flexibility, and portability, thanks to its Arduino-based structure, provide significant advantages in field tests and modular development processes.

Future studies plan to develop this system with multiple sensor configurations, wireless communication capabilities, and intelligence-supported data processing algorithms. This will enable the simultaneous monitoring of not only vibration but also multiple physical parameters such as temperature, voltage, current, and humidity, providing a comprehensive and intelligent battery management system infrastructure.

```
#include <SPI.h>
#include <SD.h>

const int sensorPin = A0; // FBG sensor output
const int threshold = 400; // Vibration threshold (may require calibration)
const int relayPin = 8; // Relay output (disconnects battery load)
const int ledPin = 7; // Warning LED
const int chipSelect = 10; // CS pin of SD card module

File Datafile;

void setup() {
Serial.begin(9600);
pinMode(sensorPin, INPUT);
pinMode(relayPin, OUTPUT);
pinMode(ledPin, OUTPUT);

digitalWrite(relayPin, HIGH); // Relay is initially open
digitalWrite(ledPin, LOW); // LED off

if (!SD.begin(chipSelect)) {
Serial.println("SD card initialization failed.");
while (1); // Stop
}
Serial.println("SD card is ready.");
}

void loop() {
int sensorValue = analogRead(sensorPin);
Serial.print("Vibration Data: ");
Serial. println(sensorValue);

// Write data to SD card
dataFile = SD.open("log.txt", FILE_WRITE);
if (dataFile) {
dataFile.println(sensorValue);
dataFile. close();
}

// Take action if vibration exceeds threshold
if (sensorValue > threshold) {
digitalWrite(relayPin, LOW); // Close the relay => cut the load
digitalWrite(ledPin, HIGH); // turn on the LED
Serial.println("WARNING: Vibration threshold exceeded, battery disabled!");
} else {
digitalWrite(relayPin, HIGH); // Relay on => battery connected
digitalWrite(ledPin, LOW); // LED off
}
```

Figure 2. Arduino-based vibration protection system for battery safety

Thanks and Information Note

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ELECTRICITY PRODUCTION FROM NATURE (*Aloe vera*)

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ABSTRACT

Energy production and conversion is one of the most important and challenging fields of science and technology in today's world. With the expansion of energy needs and the increasing world population, the development of new and sustainable methods of energy conversion is a matter of environmental protection and energy security. Among the advanced ones in this field are energy conversion systems based on biochemical and bioelectric principles that, by utilizing functions and mechanisms derived from biological structures and organisms, enable the production and conversion of energy into clean and sustainable forms. Biochemical energy conversion systems are designed to use biological methods to produce energy, including light-sensitive solar cells and biological fuel cells. These systems, by simulating and utilizing biological methods such as energy production from chemical compounds in living cells, become usable energy sources. On the other hand, bioelectrical systems are able to generate electrical energy by utilizing biological electrochemical interactions between chemicals and biological components.

One of the challenges associated with designing biochemical and bioelectrical energy conversion systems is providing methods to increase efficiency and reduce the costs of production and use of these systems.

This article presents the results of a research on the energy conversion process using plant to generate electricity for the Iranian climate.

Keywords: Electricity production, Nature power, Green energy.

Introduction

8. Electrode potential is defined as the potential of a cell containing an electrode acting as the cathode and a standard hydrogen electrode as the anode. Reduction always occurs at the cathode and oxidation at the anode. Electrode potential (Heusler, 1986) can be related to an electrochemical cell, in which two dissimilar metals conduct an electric current and are treated as they tend to release electrons. For example, when zinc metal is placed with copper metal in their respective electrolytes (Hill, 2007), zinc begins to lose electrons through an external wire connection.

9.

Materials and Methods

Materials and Methods

The materials required for the experiment are given in this PLAN. In the entire plan, an aloe vera pot and several sets of cables for the anode and cathode were used. The materials used include:

A - Pot soil substrate

B - Pot or cultivation container

C - Aloe vera plant under test

D - Ammeter (amperage measuring instrument)

E - Copper metal and copper rod

F - Zinc metal and zinc metal strip

Findings and Discussion

In this design, two materials, tin and copper, have been used in the sample pot, so that copper metal and copper rod have been used in the soil and tin metal has been used on the leaves of the aloe vera plant.

From both metals, a coated wire cable has been stretched to terminals 1 and 2, and in order to minimize manual intervention and human error, the terminal has been used in all these designs. In the photos, this item is marked with the label PLAN A.



Figure1: Copper material in the soil and tin material on the leaf

4th Day			3rd Day			2nd Day			1st Day			Material on the leaf	Material inside the soil
mV			mV			mV			mV				
C	B	A	C	B	A	C	B	A	C	B	A		
66.8	66.8	66.9	39.7	39.7	39.8	22.7	23.0	24.3	48.7	51.7	54.9		Copper
												Tin	
8th Day			**7th Day**			**6th Day**			**5th Day**			**Material on the leaf**	**Material inside the soil**
mV			**mV**			**mV**			**mV**				
C	**B**	**A**	**C**	**B**	**A**	**C**	**B**	**A**	**C**	**B**	**A**		
66.8	66.8	66.9	58.4	59.9	61.5	47.9	48.1	47.5	55.4	53.6	62.3		Copper
												Tin	
12th Day			**11th Day**			**10th Day**			**9th Day**			**Material on the leaf**	**Material inside the soil**
mV			**mV**			**mV**			**mV**				
C	**B**	**A**	**C**	**B**	**A**	**C**	**B**	**A**	**C**	**B**	**A**		
76.0	76.8	76.7	86.0	86.3	86.2	76.9	76.9	76.8	71.8	71.8	72.0		Copper
												Tin	

Table 1. Test result and voltage measurement in millivolts

After obtaining the results of the experiments and tests, the following graph was obtained. Also, the statistical results of the experiments performed are in accordance with the table below. (Table 2). The graphs and charts obtained from the results are also in accordance with Figure 2, which we will examine in the next section. (Figure 2)

Standard Error	SSD	Standard Deviation	P-Variance	Variance	Mean	Number	leaf Material on the	Material inside the soil
2.88	17.26	17.02	297.84	297.84	60.39	36.00	**Tin**	**Copper**

Table 2. Statistical results obtained from sampling

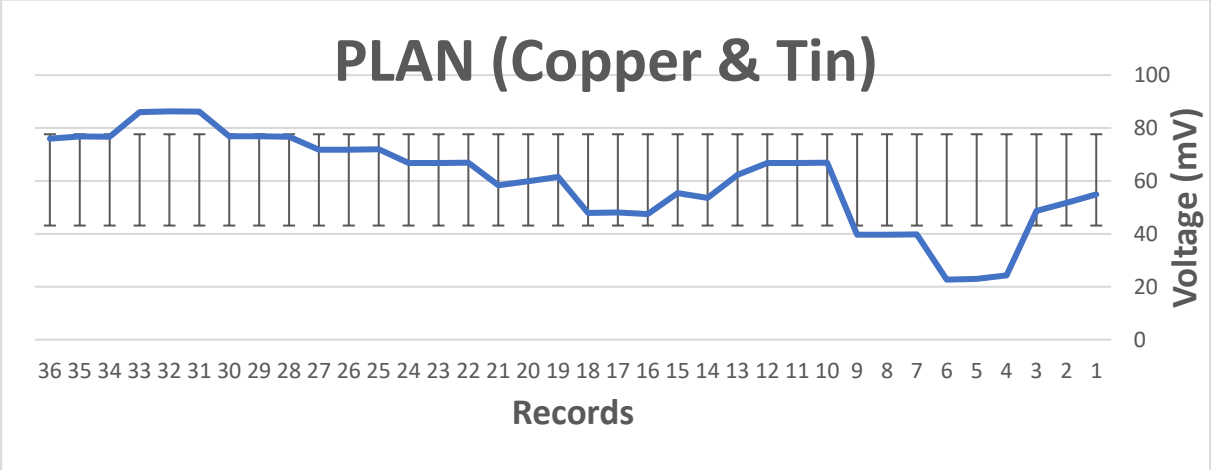


Figure 2. Graph of the results obtained from the experiment

Conclusion and Recommendations

Based on the results obtained, I suggest that by connecting plants in series and wiring them, the voltage obtained will be strengthened, and ion exchange can also be increased by replacing the soil substrate with marsh substrates. I also suggest that by using soil drainage and creating metal rods and grids in the soil, ion exchange can be increased, which will increase ion exchange and voltage, and by using this clean and useful energy, lighting can be provided at minimal cost.

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BIOFILM FORMATION INVOLVING FOOD BORNE PATHOGENIC AND HEALTH PROMOTING MICROORGANISMS

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ABSTRACT

Biofilms are organized group of microorganisms living within a self-produced matrix of polymeric substances which gets attached to several surfaces. Biofilm formation is a dynamic process and different mechanisms are involved in their attachment and growth. Extracellular polymeric substances play an important role in the attachment and colonization of microorganisms to food-contact surfaces. Biofilm formation process on food contact surfaces can have a detrimental effect on the microbial status of food. The presence of biofilm on food leads to increase risk of food poisoning from pathogens. Preventive and control strategies like hygienic plant lay-out and design of equipment, choice of materials, correct use and selection of detergents and disinfectants can be used in controlling biofilm formation on food-contact surfaces. Biofilm formation by bacteria and their subsequent resistance to antibiotic and bactericidal is slow and it brings serious threat to public health as well as domestic health. The use of health promoting microorganisms against specific biofilm-associated bacteria must be adequately explored to prevent diseases. Health promoting microorganisms in biofilm formation have been used to prevent or treat gastrointestinal tract diseases. Health promoting microorganisms have beneficial impact on oral microbiota. Dental caries and diarrhea can be treated and prevented prophylactically by the use of health promoting microorganisms.

Keywords: Biofilm; Colonization; Microbiota; Extracellular polymeric substances; Pathogens; Control

Introduction

Biofilms are organized group of microorganisms living within a self-produced matrix of polymeric substances which gets attached to several surfaces (Franklin *et al.,* 2011). These collectives of microbes are found to be ubiquitous in almost every environment. Biofilms may be

form on solid biological or non-biological surfaces and are medically important, accounting for most of the microbial infections in the body. Biofilms are composed by a mass of microorganisms attached to a surface, such as a surface of a medical device, and the associated extracellular substances produced by one or more of the attached microorganisms. These biofilms are prevalent on most wet surfaces in nature. Biofilms have been seen to be present on liquid surfaces as a floating mat and in submerged state also. Biofilms contain either homogenous or heterogeneous communities of microorganism, embedded on a matrix of extracellular polymeric substances (Flemming and Wingender, 2010). Extracellular polymeric substances mainly consist of polysaccharides, but other biomolecules like proteins, lipids and nucleic acids are also present in extracellular polymeric substances. Polymers like glycopeptides, lipids and lipopolysaccharides form a scaffold and hold the biofilm together. Extracellular polymeric substances of biofilms are hydrogels which exhibit viscoelastic behavior. These properties allow the biofilms to withstand mechanical stress. The nutrients that are present in the matrix of extracellular polymeric substances are trapped for the use of bacteria. The water in the matrix is efficiently trapped by hydrogen bonding with the hydrophilic polysaccharides in extracellular polymeric substances. Genetic and environmental factors contribute towards the microbial biofilm formation. Bacteria can adapt to different environmental conditions by modifying their biofilm structure. The communities of microorganism of biofilms usually take part in the production and degradation of organic matter, the remediation of many environmental recalcitrant pollutants, the cycling of nitrogen, sulphur and many metals, in the purification of sewage, in the treatment of groundwater contaminated with petroleum, and in the process of nitrification, microbial biofilms play a major role. Rhizospheric soil has increase in soil fertility and plant growth becaue of the activities of microbial biofilms. In acid mine drainage (at a pH of 1), microbial biofilm plays an important role in the cycling of sulphur. The polymers of microbial biofilm on enhances the degradative ability of the organisms. Microorganisms in biofilm on polymer surface attained higher fitness in reproductive competency (Foreman and Wormald, 2010). Extracellular enzymatic activities in extracellular polymeric substances assist detoxification of heavy metals by transformation and subsequent precipitation in the exopolymeric mass. Microorganisms in biofilm exhibited higher metabolic functional diversity and metabolic cooperation than microorganisms in planktonic form. The enhanced metabolic functional diversity and phenotypic plasticity in biofilm residing microorganisms facilitate improved degradation of the polymer. Biofilm forms complexes with positively charged metal cations causing metal immobilization within the exopolymeric network.

Biofilms have many negative activities, the immune responses are not much effective against bacterial biofilms in comparison with their planktonic counterpart . Many bacterial pathogens that are initially considered as strictly extracellular can persist inside the host by the formation of biofilm through the process of adaptation that results in the evasion of the bacteria from innate immunity of the host. The evasion of biofilms from host innate response proves harmful to the host, as the inflammatory influx released by the body in response to the bacterial infection can damage the host tissues. The presence of biofilms in bacterial infections can increase the pathogenicity of the bacteria and protects the bacteria from being destroyed by external

treatment. Biofilm may exist in a variety of microbial infections as well as on the surface of the medical implants including catheters (Vasudevan, 2014). Some populations of biofilm-associated bacteria show antibiotic resistance, reduction in growth rate, secretion of different surface molecules and virulence factors and facilitates gene transfer among bacteria which can lead to increase in the number of virulent strains (Cortes *et al.,* 2011).

Biofilm matrix retards the diffusion of antibiotics through their extracellular polymeric substances , and this increases drug resistance among microbial population. Another possible mechanism of drug resistance of microbial biofilm can be mediated by the differential gene expression of biofilm cells compared to its planktonic form. Apart from this drug resistance, biofilms also exhibit resistance against bacteriophages, chemical biocides, amoebae, etc., (Costerton *et. al.,* 1999).Host immune responses is ineffective against microbial biofilms because biofilm cells regularly change the surface antigens through rapid alteration in gene expression. However, host immune responses against biofilm prove harmful for body tissues as the secretion of inflammatory cytokines at the site of biofilm formation is unable to destroy the biofilm structure but rather can cause wounds at the surrounding tissues. By these activities biofilm environment protects bacteria from external assaults, predator attack and chemical treatment like antibiotics.

Discussion and Findings: Stages of Biofilm Formation: Microbial biofilm grows through five consecutive stages such as initial reversible attachment, irreversible attachment, maturation stage I, maturation stage II and dispersion. Biofilm growth is guided by a sequence of physical, chemical and biological processes. Biofilm formation depends on an interaction between three main components: the bacterial cells, the attachment surface and the surrounding medium.

The first stage involves planktonic microbial cells adhering to the surface either by physical forces or by bacterial appendages such as pilli or flagella. A lot of factors like surface functionality, temperature and pressure can modulate the bacterial adhesion greatly. Attachment of a microbial cell to a surface is known as adhesion, whereas the attachment among microbial cells is termed as cohesion. Physical forces related to bacterial adhesion to surfaces comprise the van der Waals forces, steric interactions and electrostatic (double layer) interactions.

In the second stage, some of the reversibly attached cells remain immobilized and become irreversibly adhered when the attractive forces are greater than repulsive forces. It has been reported that the physical appendages of bacteria like flagella, fimbriae and pili overcome the physical repulsive forces of the electrical double layer of the cell and the surface and consolidate the interactions between bacteria and the surface. Cell surface hydrophobicity contributes a crucial role in biofilm formation when the bacteria adhere to a hydrophobic nonpolar surface because the hydrophobic interaction between the surface and the bacteria reduces the repulsive force between them. In the first and second stages of biofilm formation microbial cells initiallyare loosely associated with the concerned surface, which is then succeeded by specific and strong adhesion.

The third stage of biofilm formation is the maturation, In this stage, microbial cells start communicating among each other by the production of auto inducer signals (Vasudevan, 2014) that resulted in the expression of biofilm-specific genes. In this stage, microorganism secretes a matrix of extracellular polysaccharide substances to stabilize the biofilm network. Microbes like *P. aeruginosa* makes and releases three polysaccharides, namely alginate, Pel and Psl which provide the stability to the biofilm. Alginate interacts with nutrients and water and supplies nutrients to the biofilm (Rasamiravaka *et al*., 2015). Pel (glucose rich polysaccharide) and Psl (pentasaccharide) act as a scaffold for the structure of the biofilm. In addition to extracellular polysaccharide substances, thee DNA is also responsible for cellular

communication and stabilization of *P. aeruginosa* biofilm. Fresh *Pseudomonas* biofilms are more susceptible to DNase treatment compared to mature biofilm, suggesting the stabilizing role for e DNA during the initial biofilm stages when extracellular polysaccharide substances components are less. In this stage, the biofilm becomes multi-layered and their thickness is increased up to 10 µm (Wade, 2013)

In the fourth stage, the size of the microcolony increases and its thickness reaches to about 100 µm. Microcolonies in biofilm quiet often contain diverse microbial communities. These multispecies micro-consortia function in a relatively complex and coordinated manner. Their close proximity enhances substrate exchange, distribution of metabolic products and removal of toxic end products. For example, degradation of complex organic matter into methane and carbon di oxide during anaerobic digestion requires the involvement of at least three types of bacteria. Fermentative bacteria start the catabolism of complex organic compounds and produces acids and alcohols from the organic compounds. These substrates are then consumed by acetogenic bacteria as their substrates. Methanogen gains energy by converting acetate, carbon di oxide and hydrogen to methane. Biofilm offers a perfect environment for the establishment of syntrophic association (Flemming and Wingender, 2010). Syntrophism is a type of symbiosis in which two metabolically distinct microbes depend on each other in order to exploit certain substrates for their energy source. The third and fourth stages comprise the aggregation of the cells, forming microcolonies followed by the growth and maturation of the adhered cells. In this maturation stage, biofilm becomes adopted with the external condition by manipulating its structure, physiology and metabolism.

The fifth stage is the dispersion, it involves the shedding of the biofilm and return of sessile cells to the motile form. Finally, in this stage, biofilm spreads and colonizes new surfaces. In this phase, the microbial community inside the biofilm produces different saccharolytic enzymes which break the biofilm stabilizing polysaccharides and releases surface bacteria residing on the top of biofilm structure for colonization to a new surface (Rodrigues et. al., 2011)

Signalling events in Biofilm Formation

Formation of a biofilm is dependent on the interaction between the environmental stimuli and the reciprocation of the corresponding signalling events by the microorganisms (Fridman *et. al.,* 2013). There are many sensing systems that can integrate the environmental stimuli into signalling pathways. These sensing systems can induce responses from two-component systems (TCS), extra cytoplasmic function (ECF) signaling pathway and quorum sensing (QS) events. Secondary messengers like c-di-GMP (cyclic guanosine monophosphate**)** are also involved in triggering biofilm formation . In the formation of biofilm, a coordinated network of gene expression is required in a stepwise manner. These signalling events play a very important role for microbial biofilm formation by developing adaptive responses against external and internal stimuli (Bordi and de Bentzmann, 2011).

Biofilm and Drug Resistance

Antibiotic resistance of free-living bacteria usually involves inactivation of the antibiotic, modification of targets, and exclusion of the antibiotic. The acquisition of specific genetic factors, such as genes for β-lactamase are required for these actions. One of the most important aspects of bacterial biofilm formation is the increased resistance of the constituent microbes to

antibiotics and other stressors. The structure of the biofilm and the characteristics of the sessile cells produce resistance towards the antimicrobial agents which lead to a protected environment against adverse conditions and the host's defenses. Bacterial biofilm provides a protective mechanism for the cells to be less susceptible to antibiotics, dispersal of biofilm for removal of cells outside the matrix enables antibiotics for treatment of bacterial infections. Removal of these cells from the matrix of the biofilm renders them to be susceptible to antibiotics. Free living bacteria are more susceptible to antibiotic treatment and to host defense mechanisms. The minimal inhibitory concentration and minimal bactericidal concentration of antibiotics to biofilm-growing bacteria being up to 100 -1000 fold higher than for free bacteria, and possibly 150-3000 times more resistant to disinfectant (Bordi and Bentzmann, 2011

Biofilm Formation in Food Industry: industry of fermented food products (sausages, cheeses etc), biofilm formation by some useful and technological bacteria (e.g. staphylococci, lactococci, lactobacilli) can be desirable, as a mean of the enhancement of food fermentation process, and more importantly as a mean of protection against the establishment of pathogenic biofilms (Chorianopoulos *et al*., 2008). Many pathogenic organsims adhere to food surfaces these Include foodborne bacterial biofilm such as *L. monocytogenes*, *Salmonella enterica*, *Yersinia enterocolitica, Campylobacter jejuni, Escherichia coli* O157:H7 Modern food processing supports and selects for biofilm forming bacteria on food-contact surfaces due to mass production of products, lengthy production cycles and vast surface areas for biofilm development. *In situ* biofilms have been recognized in various food processing industries, such as processors of cheese and other milk products, raw and cooked/fermented meats, raw and smoked fish etc. The attachment of bacterial pathogens to food surfaces such as *Escherichia coli* to beef muscle and adipose tissue (Rivas *et al*., 2006) and *S. Typhimurium*, *Yersinia enterocolitica* and *L. monocytogenes* to pork skin **(Wade, 2013)**

Prevention of Biofilm Formation: Strategies to plan against bacterial biofilm must be achieved by prevention of biofilm formation rather than dispersal of the formed biofilm. Strategies for prevention of biofilm formation include both chemical and mechanical methods. Prevention are carried out by the application of anti-microbial coating, anti-peptides, chelating agents, anti-biofilms enzymes, anti-adhesion agents and bacterial anti-biofilm polysaccharides (Reid, 2012)

Health Promoting Microorganisms

Health promoting microorganisms (probiotics) is a proposed alternatives to antibiotic treatment (Cotter *et al*., 2013). Biofilms of health promoting microbes in the oral cavity, gastro intestinal tract, urogenital and respiratory tract prevent establishment of pathogenic microbes.

Conclusion And Recommendation

Biofilms are commonly defined as communities of microorganisms attached to a surface, producing an extracellular matrix, in which these microorganisms are embedded. Biofilms are very diverse and unique, not just to the microorganism, but to the particular environment in which they are being formed. Pathogenic biofilms have been of considerable interest in the context of food safety. In particular, biofilm formation by bacteria is a serious concern in food industry, since the persistence of this bacterium in biofilms formed on food-contact surfaces may become a constant source of product contamination.

Particularly challenging is the attempt to understand the complexity of the interactions within a biofilm community, since these interactions between the different species influence the final outcome of this community. A clearer understanding of the factors which influence microbial attachment to abiotic surfaces could provide the information necessary to modify processes in food processing environments in order to reduce microbial persistence and therefore reduce the contamination of food products.

Biofilm formation by bacteria and their subsequent resistance to antibiotic and bactericidal is a slow and it brings serious threat to public health as well as domestic health. The identification of health promoting microorganisms for the inhibition of intercellular communications will provide the means to inhibit biofilm development since intercellular communications are certainly required for biofilm development and persistence, the use of probiotics against specific biofilm-associated bacteria must be adequately explored to prevent diseases. To better control
biofilms in food borne pathogen adequate hygienic practices must be observed.

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SOIL POLLUTANTS AND IMPACT ON AGRICULTURAL CROPS

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ABSTRACT

Soil pollution is an escalating environmental challenge that threatens global agricultural sustainability, food security, and ecosystem health. This study explores the types, sources, and impacts of soil pollutants on agricultural crops, with particular emphasis on recent scientific findings. Key contaminants include heavy metals (e.g., lead, cadmium, arsenic), synthetic pesticides, petroleum hydrocarbons, microplastics, and excess nutrients like nitrates and phosphates. These pollutants originate primarily from industrial discharges, excessive agrochemical use, urbanization, and poor waste management practices. Once in the soil, these substances alter microbial dynamics, reduce fertility, degrade structure, and inhibit vital plant physiological processes such as nutrient uptake, photosynthesis, and root development. For instance, heavy metals interfere with plant metabolism, while microplastics and petroleum hydrocarbons impair soil porosity and water retention. Regional case studies from Asia, Africa, and Europe reveal how pollution diminishes crop yields and quality, with significant implications for food safety due to bioaccumulation and biomagnification. Mitigation strategies such as bioremediation, organic farming, and precision agriculture are discussed alongside policy recommendations aimed at reducing pollutant input and enhancing soil monitoring. This review underscores the urgent need for integrated, multidisciplinary approaches to restore and protect soil health. By synthesizing current research and presenting practical interventions, the work contributes to ongoing efforts to promote resilient agricultural systems and environmental sustainability in the face of mounting anthropogenic pressures.

Keywords: Soil contamination, agricultural productivity, heavy metals, crop toxicity, soil management

Introduction

Soil is an essential natural resource and a fundamental component of terrestrial ecosystems. It plays a pivotal role in sustaining life on Earth by supporting agricultural productivity, regulating the hydrological cycle, mediating biogeochemical processes, and acting as a medium for plant growth, nutrient cycling, and water filtration (FAO, 2022). Healthy soils are the foundation of food security, enabling the cultivation of crops that feed billions globally. However, in recent decades, the quality and functionality of soils have been severely compromised due to increasing anthropogenic pressures.

Modern agricultural practices, industrial expansion, improper waste disposal, and rapid urbanization have significantly contributed to the accumulation of pollutants in soils. These pollutants include a wide range of substances such as heavy metals (e.g., lead, cadmium, arsenic), synthetic pesticides, industrial chemicals, petroleum hydrocarbons, and emerging contaminants like microplastics and pharmaceutical residues (Zhang et al., 2021; Ahmed et al., 2023). The presence of these pollutants disrupts soil microbial communities, degrades soil structure and fertility, and adversely affects plant health, ultimately posing a threat to agricultural sustainability and food safety.

Heavy metals are among the most persistent and toxic soil contaminants. Introduced mainly through industrial emissions, mining activities, sewage sludge, and the overuse of phosphate fertilizers, heavy metals accumulate over time and interfere with plant metabolic processes (Xu et al., 2021). Pesticides, though designed to target pests, often persist in the environment long after application. Their residues can alter soil enzymatic activity, reduce biodiversity, and accumulate in crop tissues, entering the food chain (Singh & Prasad, 2020). Similarly, petroleum hydrocarbons—originating from oil spills, vehicular emissions, and industrial waste—bind to soil particles, decreasing porosity and water retention while releasing toxic compounds that impair root development and photosynthesis (Li et al., 2022).

One of the more recent concerns is the growing presence of microplastics in agricultural soils. These plastic fragments, often originating from plastic mulch films, compost made from household waste, or irrigation with contaminated water, persist in the soil environment and have been found to reduce soil aeration, interfere with root-soil contact, and inhibit nutrient uptake in crops (Zhang et al., 2021). Furthermore, excessive use of nitrogen and phosphorus-based fertilizers contributes to nutrient pollution, which not only acidifies soils and diminishes microbial diversity but also leads to eutrophication of nearby water bodies, compounding the environmental impact (Ahmed et al., 2023).

Soil pollution has direct and indirect consequences for crop growth and yield. Contaminants can lead to stunted growth, reduced seed germination, poor root development, and accumulation of toxic substances in edible plant parts (Zhao et al., 2020). These changes not only reduce the quality and quantity of agricultural produce but also pose long-term risks to human and animal health through bioaccumulation and biomagnification. Moreover, polluted soils are less resilient to climate variability and more susceptible to erosion and degradation.

Addressing soil pollution requires a multidisciplinary approach, integrating environmental science, agronomy, toxicology, and policy development. Sustainable soil management practices such as phytoremediation, organic farming, and precision agriculture can help mitigate the negative impacts. However, these strategies must be supported by effective regulatory frameworks, farmer education, and investments in soil health monitoring systems.

This review provides a comprehensive overview of the types and sources of soil pollutants, their pathways of contamination, and their impacts on agricultural crops. It draws upon recent

scientific studies and evidence from 2020 onwards to highlight emerging trends, case studies, and potential solutions for reversing soil degradation and promoting sustainable agricultural development.

Case Studies and Regional Perspectives

Asia: In China and India, heavy metal contamination due to industrial effluents and overuse of fertilizers has resulted in reduced yields of rice and wheat. A study by Chen et al. (2021) showed that cadmium concentrations above 3 mg/kg significantly reduce rice grain quality and increase health risks for consumers.

Africa: In Nigeria, improper disposal of agrochemicals and electronic waste contributes to lead and arsenic contamination in agricultural soils. These pollutants are known to stunt the growth of maize and cassava, vital food crops in the region (Obi et al., 2023).

Europe: European studies have reported high concentrations of microplastics in soilsunder intensive horticultural production. In the Netherlands, microplastic particles were found to reduce lettuce biomass by 15% over two growing seasons (van den Berg et al., 2021).

Table 1 Mitigation Strategies

S/N	Mitigation Strategies	Description
1	Bioremediation	Bioremediation involves the use of microorganisms and plants to degrade, transform, or immobilize pollutants. Phytoremediation using hyperaccumulator species such as Brassica juncea is effective in extracting heavy metals (Singh et al., 2022).
2	OrganicFarming and Precision Agriculture	Minimizing the use of synthetic agrochemicals and adopting precision agriculture techniques can reduce the accumulation of pollutants. Organic amendments such as compost and biochar also improve soil health and immobilize toxic elements (Ahmed et al., 2023).
3	Policy and Regulation	Strengthening regulatory frameworks for the disposal of industrial waste and pesticide use is critical. Monitoring and soil testing programs should be integrated into national agricultural strategies (FAO, 2022).

Conclusion

Soil pollution represents a multifaceted challenge with profound implications for agricultural productivity, food safety, and environmental health. Addressing the issue requires a combination of scientific innovation, policy reforms, and community-based interventions. Sustainable soil management must become a cornerstone of future agricultural planning to safeguard crops and ensure long-term food security.

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THE INFLUENCE OF SOCIAL MEDIA INFLUENCERS ON GENERATION Z: AN EXAMINATION OF PURCHASING BEHAVIORS AND DIGITAL OPINION LEADERSHIP

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ABSTRACT

This study examines the influence of social media influencers on the consumption practices of Generation Z within the context of increasing digitalization and the central role of social media in daily life. Social media platforms have surpassed the boundaries of traditional advertising, giving rise to an interaction-based marketing model that directly shapes consumer behavior. At the heart of this transformation are influencers, who function not only as product promoters but also as trust-building figures and digital opinion leaders among their followers. Within the scope of this study, the ways in which Generation Z—often referred to as digital natives—access information, make decisions, and form consumption habits are analyzed in depth. Using in-depth interview methodology, the research explores Generation Z's perceptions of trust in influencers, the impact of influencers on purchasing decisions, and the perceived authority of influencers within digital spaces. Findings reveal that Generation Z places greater trust in influencers who communicate authentically and align with their personal values, even when the content is sponsored. This has led brands to radically transform their marketing strategies, prioritizing social media collaborations over traditional advertising. A more nuanced analysis of the findings shows that the influence of these figures extends beyond economic motivations. When Generation Z individuals identify with an influencer's lifestyle, value propositions, and sense of social responsibility, they tend to form a stronger emotional connection with the products and brands endorsed. Thus, purchasing decisions become a form of identity performance, with influencers acting as catalysts in this process. As media literacy increases among Generation Z, hidden sponsorships, product placements, and perception management strategies are more easily detected, making it increasingly challenging for influencers to sustain trust-based relationships. This study emphasizes the need to reassess the role of influencers in the contemporary digital ecosystem and provides a comprehensive analysis of the multi-layered processes shaping Generation Z's consumer behaviors.

Keywords: Generation Z, Purchasing Behavior, Influencer, Social Media, Digital Marketing, Digital Opinion Leadership

INFLUENCERLARIN Z KUŞAĞI ÜZERİNDEKİ ETKİSİ: SATIN ALMA DAVRANIŞLARI VE KANAAT ÖNDERLİĞİ ÜZERİNE BİR İNCELEME

ÖZET

Bu çalışma dijitalleşmenin hız kazanmasıyla birlikte sosyal medyanın bireylerin günlük yaşamlarında merkezi bir konum elde etmesi sürecinde, influencerların Z kuşağının tüketim pratikleri üzerindeki etkisini incelemektedir. Sosyal medya platformları, geleneksel reklamcılığın sınırlarını aşarak, bireylerin tüketim davranışlarını doğrudan etkileyen etkileşim temelli yeni bir pazarlama anlayışı geliştirmiştir. Bu dönüşümün merkezinde yer alan influencerlar, yalnızca ürün tanıtımı yapan figürler değil, aynı zamanda takipçileri nezdinde güven inşa eden ve kanaat önderi işlevi gören aktörler hâline gelmiştir. Bu çalışma kapsamında, dijital yerliler olarak adlandırılan Z kuşağının bilgiye ulaşım biçimi, karar alma süreçleri ve tüketim alışkanlıklarındaki değişimler derinlemesine analiz edilmiştir. Bu bağlamda, araştırmada derinlemesine mülakat yöntemi kullanılarak, Z kuşağının influencerlara yönelik güven algıları, satın alma kararlarındaki etkileri ve dijital platformlarda sahip oldukları otorite boyutları ele alınmıştır. Elde edilen bulgular, Z kuşağının, sponsorluk içeriği taşısa bile sahip oldukları değerlerle örtüşen, özgün ve samimi iletişim kuran influencerlara daha fazla itibar ettiğini ortaya koymaktadır. Bu durum, markaların pazarlama stratejilerini radikal biçimde dönüştürmekte ve geleneksel reklam yöntemleri yerine sosyal medya iş birliklerine öncelik vermelerini zorunlu kılmaktadır. Elde edilen bulguların daha derinlemesine analizi, influencerların Z kuşağı üzerinde oluşturduğu etkilerin yalnızca ekonomik motivasyonlarla sınırlı olmadığını göstermektedir. Z kuşağı bireyleri; influencerların yaşam tarzları, değer önermeleri ve sosyal sorumluluk anlayışları ile özdeşlik kurduklarında, söz konusu fenomenlerin önerdiği ürün ve markalarla daha güçlü bir bağlılık geliştirmektedir. Bu durum uygulamaya geçirdikleri tüketim kararlarının ürünün özelliklerinden ziyade temsil ettiği kimlik ve değerler bütününe göre şekillendiğini ortaya koymaktadır. Dolayısıyla Z kuşağı açısından satın alma süreci bir tür kimlik performansına dönüşmekte ve influencerlar söz konusu sürecin katalizörü rolünü üstlenmektedir. Z kuşağının medya okuryazarlığının artmasıyla birlikte, içeriklerin perde arkasındaki sponsorluk ilişkileri, ürün yerleştirme stratejileri ve algı yönetimi taktikleri daha kolay teşhis edilmekte ve influencerlar için sürdürülebilir bir güven ilişkisi kurmayı zorlatırmaktadır. Bu çalışma influencerların modern dijital platformlar içerisindeki konumlarının yeniden değerlendirilmesi gerektiğini ortaya koymakta, Z kuşağının tüketim pratiklerini etkileyen süreci detaylı biçimde irdelemektedir.

Anahtar Kelimeler: Z Kuşağı, Satın Alma Davranışı, Influencer, Sosyal Medya, Dijital Pazarlama, Dijital Kanaat Önderliği.

GİRİŞ

Günümüzde Dijital iletişim araçları yaşamın merkezine konumlandırılmaktadır. Özellikle Z kuşağının tüketim alışkanlıklarının sosyal medya içerikleri doğrultusunda şekillendiği görülmektedir. Bu bağlamda araştırma, influencerların yalnızca birer ürün tanıtıcısı değil, aynı zamanda düşünce biçimlerini, değer yargılarını ve yaşam tarzlarını etkileyen kanaat önderleri olarak nasıl konumlandıklarını ortaya koymayı hedeflemektedir. Çalışmanın temel amacı sosyal medya fenomenleri olarak adlandırılan influencerların Z kuşağı üzerinde oluşturduğu etkiyi iki ana eksende incelemektir: Satın alma davranışları üzerindeki etkileri ve kanaat önderliği rolleri.

Sosyal medya ve sosyal ağ platformları, kullanıcıların günlük yaşamlarının bir parçası haline gelmiş, bu mecralarda kendine has tarzlarıyla öne çıkan ve belirli kitlelere hitap eden yeni, tanınan ve bilinen kişiler ortaya çıkmaya başlamıştır. Bu kişiler, "influencer" olarak adlandırılmakta ve sosyal medya üzerinde belli bir etki alanına sahip bireyler olarak kabul edilmektedir. Farklı konularda içerik üreten influencerlar; seyahat, yemek, moda gibi alanlarda takipçilerine tavsiyelerde bulunurlar. Influencer, sosyal medya ortamlarında yüksek takipçi sayısına sahip, belirli bir konuda içerik üreterek kullanıcı davranışlarını etkileyebilen birey olarak tanımlanır (Booth & Matic, 2011). Bununla birlikte, sosyal medya aracılığıyla bir ürün ya da hizmet hakkındaki görüş ve deneyimlerini takipçileriyle paylaşarak tanıtımını yapan kişi, ya da sahip olduğu dijital mecralar üzerinden belirli bir grubu etkileyebilen kişi anlamlarına da gelir. Aynı zamanda bu kişiler "fenomen" olarak da tanımlanabilir (Tureng). Influencerlar deneyimledikleri hizmet ve ürünlerle ilgili bilgileri takipçilerine aktararak onları yönlendirme gücüne sahiptir. Toplumsal yapının dönüşmesi ve teknolojik gelişmelerle birlikte, günümüzde sosyal medya sayesinde toplumun her kesiminden bireylerin tanınma ve ünlü olma şansı doğmuştur. Önceden belirli bir yetenek veya sınıfsal ayrıcalık gerektiren ünlü olma durumu, artık sosyal medya aracılığıyla daha geniş bir kitleye yayılmıştır (Tokay ve Akın, 2021; Tokay ve Akın, 2020; Mert, 2018).

Tek yönlü iletişimin hâkim olduğu geleneksel dönemin ardından gelen dijital çağ, sosyal medya platformlarının yükselişine sahne olmuştur. Bu platformlar influencer pazarlama için geniş fırsatlar sunmuştur. Rekabet ortamında öne çıkmak isteyen markalar da bu pazarlama yöntemini bilinçli ve stratejik şekilde kullanmaya yönelmektedir. Ulusal/uluslararası birçok firmanın pazarlama yöneticileri, sosyal medyada yüksek takipçi sayısına sahip ve markalarını doğru temsil edebilecek influencerlarla sponsorluk anlaşmaları yapmaktadır. Bu iş birlikleri sayesinde şirketler, sosyal medyada ürün/hizmetlerini tanıtma imkânı bulmakta, ürettikleri içeriklerin ağızdan ağıza yayılmasıyla oluşan fırsatlardan faydalanmaktadır (Kırçova ve Enginkaya, Ebru 2015). Z kuşağı, geleneksel reklam stratejilerine göre dijital ortamda üretilen özgün ve samimi içeriklere daha fazla güven duymakta ve markaların hedef kitlelerine ulaşma biçimlerini yeniden şekillendirmelerine zemin oluşturmaktadır. Dolayısıyla bu konunun ekonomik, sosyal ve kültürel boyutları akademik olarak incelenmesini zorunlu kılmaktadır.

Çalışma akademik literatüre katkı sağlarken pazarlama iletişimi, dijital medya ve tüketici davranışları alanlarında çalışan profesyonellere Z kuşağı ile daha etkili iletişim kurmanın yollarını göstermeyi amaçlamaktadır.

1. Dijitalleşme ve Sosyal Medyanın Yükselişi

Dijital dilin kökenleri, 19. yüzyılda matematikçi Gottfried Wilhelm Leibniz'in 0 ve 1 değerlerinden oluşan ikili aritmetik sistemi keşfetmesiyle atılmıştır. Bu sistem günümüzde dijital iletişimin ve bilgi teknolojilerinin temelini oluşturmaktadır. Dijital dilde her harf, sayı ve sembol, belirli bir kodlamaya karşılık gelir. Bilgisayarlar ve teknolojik cihazlar, tüm işlemlerini

bu kodlar üzerinden gerçekleştirir. Bu nedenle günümüz dijital dünyası, adeta ikili (binary) sistemin hâkim olduğu bir yapıya dönüşmüştür (Demir Askeroğlu, 2017).

Tarihsel süreçte medya her dönemde insan yaşamında merkezi bir rol oynamıştır. İlk çağda güvercin, imparatorluk dönemlerinde ulaklar aracılığıyla uzak coğrafyalara iletilen haberler günümüzde sosyal medya platformlarında saniyeler içinde kıtalararası yayılmaktadır**.** Bu dönüşüm, iletişimin toplum üzerindeki etkisini de derinleştirmiştir. Özellikle dijital medya araçlarının etkin kullanımı, etki ve tepki döngülerinde hız ve yayılım açısından belirgin artışlara yol açmış, yeni iletişim teknolojileri, sosyal yaşamın ayrılmaz bir parçası hâline gelmiştir (Çelik, 2022). Sosyal medya, kapsamlı sosyal etkileşimi mümkün kılan ve kullanıcılar arasında dijital topluluklar oluşturan web tabanlı platformlar olarak tanımlanabilir. Kullanıcılar bu platformlar aracılığıyla çevrim içi profiller oluşturmakta, ağlar kurmakta ve iletişim kurmaktadır. Profil sayfaları, bireylerin dijital kimliklerini temsil etmekte ve kişisel web sitesi işlevi görmektedir. Bu sayfalarda bireyler, demografik bilgilerinin yanı sıra eğitim düzeyleri, politik ve dini görüşleri, ilgi alanları, sosyal çevreleri ve gündelik yaşamlarına dair detayları paylaşmaktadır (Akar, 2010).

2. Z Kuşağı'nın Medya ve Tüketim Alışkanlıkları

Z kuşağı, önceki nesillerden farklı olarak sosyal medya ortamına doğmuş ve bu mecralarla iç içe büyümüş bir kuşaktır. Bu kuşak, sosyal medya platformlarını ağırlıklı olarak iletişim kurmak, bilgi edinmek ve eğlenmek amacıyla kullanmaktadır. Eğlencenin yanı sıra ürün ve hizmetler hakkında bilgi toplamak, fiyat karşılaştırması yapmak, sosyal ilişkilerini sürdürmek ve çevrim içi iş birlikleri geliştirmek gibi amaçlarla da bu mecraları etkin bir şekilde kullanmaktadır (Hidvégi & Kelemen-Erdős, 2016; Sarıoğlu & Özgen, 2018). Sosyal medyada aktif zaman geçiren genç kullanıcılar, markaların dijital platformlarda görünür olmasını ve çevrim içi alışveriş imkânı sunmalarını önemli bulmaktadır. Ayrıca Z kuşağı, satın aldığı ürünlerin ve yaşadığı deneyimlerin özgün ve kişiselleştirilmiş olmasına büyük önem atfetmektedir (Baldwin, 2018).

Z kuşağının alışveriş öncesi bilgi ihtiyacını karşılama oranları da bu kuşağın dijitalleşmeye olan yatkınlığını ortaya koymaktadır. Buna göre, bilgi kaynakları arasında internet %82,1 ile ilk sırada yer almakta, bunu %60 ile aile ve arkadaş görüşleri, %15,6 ile ürün katalogları, %11,3 ile broşürler ve %6,7 ile satış danışmanları izlemektedir (Hidvégi & Kelemen-Erdős, 2016). Türkiye'de Z kuşağı üzerine yapılan bir araştırmada, katılımcıların en çok kullandığı sosyal medya platformunun Instagram, ardından Facebook olduğu belirlenmiştir. Kullanım amaçları arasında sohbet ve eğlence ilk sıralarda yer almaktadır (Kılıç & Karadayılı, 2017). Kuşaklar arası satın alma davranışları üzerine yapılan bir çalışmada, Z kuşağının en sık alışveriş yaptığı yerin alışveriş merkezleri olduğu, aynı zamanda interneti en yoğun kullanan kuşak olduğu ve satın alma kararlarında ürünün fiyatına en çok dikkat eden grup olarak öne çıktığı tespit edilmiştir (Sarı & Harta, 2018). Benzer bir çalışmada ise Z kuşağı tüketicilerinin Y kuşağından farklılaşan özelliklere sahip olduğu ortaya konmuştur. Bu özellikler arasında mükemmeliyetçilik, marka ve modaya düşkünlük, düşünmeden alışveriş yapma eğilimi, bilgi karmaşası yaşama ve alışverişten kaçınma gibi eğilimler öne çıkmaktadır (Özden, 2019).

3. Influencer Kavramı ve Dijital Kanat Önderliği

Karar alma süreçlerinde insanların diğer bireylerden etkilenmesi insanlık tarihi boyunca gözlemlenen evrensel bir gerçekliktir. İnsanoğlu, doğası gereği tercihlerde bulunabilmek için güvenilir bilgi kaynaklarına yönelmektedir. Bu bilgi arayışı sürecinde, sevilen, saygı duyulan, güvenilen ve fikirlerine itibar edilen bireylerin, yani "kanaat önderlerinin" rolü kritik bir durak olarak öne çıkmıştır. Günümüzde kanaat önderlerinin toplumsal etkisi ve hedef kitlelerine ulaşma biçimleri iletişim teknolojilerinde yaşanan gelişmelere bağlı olarak önemli dönüşüm

geçirmiştir. Söz konusu kişiler dijital platformlar aracılığıyla bireyleri etkileme, yönlendirme ve bilgilendirme işlevlerini yerine getirmekte; geleneksel "kanaat önderi" kavramı sosyal medyada "influencer" kimliğiyle yeniden tanımlanmaktadır (Kazancı, 2022). Sosyal medya vazgeçilmez bir araç olarak kullanılmaya başlanmış ve toplumsal hayatta önemli bir konumu işgal etmiştir. Söz konusu bu konumundan işletmelerde kendilerine pay çıkararak sosyal medya uzantılı pazarlama yaparak tüketicilere ulaşmaya çalışmaktadır (Terkan, 2014). Tüketiciler artık mal ve/veya hizmeti alırken öncelikle sosyal medya, facebook, instagram vb sitelerden gerçek kullanıcı yorumlarına bakarak işlem başlatmaktadırlar. Diğer kullanıcılar gibi kendileri de ürün ve/veya hizmet hakkında görüşlerini kullanıcılara ve alıcılara iletmektedirler (Hashımzada, 2015).

Tüketici satın alma süreci, tüketicinin satın alma öncesi, satın alma aşaması ve sonrasına ait süreçleri kapsamaktadır. Tüketicinin neden satın aldığı sorusuyla da yakından ilişkili olan bir kavramdır. Süreç, satın alma davranışını bir karar süreci olarak incelemektedir. Tüketici satın alma karar süreci, fiili satın almadan daha önce başlamakta ve satın alımdan çok daha sonra da sonuçlarını devam ettirmektedir (Tek ve Özgül, 2005). Tüketicinin neyi, nereden, hangi şekilde, ne zaman, niçin satın aldıklarını açıklamaya çalışan tüketici davranışlarıdır (Akturan, 2007). Tüketicilerin online tüketici satın alma davranışlarında, online alışverişle ilgili üç temel fikre sahip oldukları görülmektedir. Bunlar; zamandan tasarruf, uygun fiyat, istek ve ihtiyacı doğrultusunda kendisine en uygun ürünü bulmaktır (Punj, 2011).

Sosyal medya platformlarında yüksek ikna gücüne ve etki potansiyeline sahip bireyler olan influencerlar; ünlüler, internet fenomenleri, blog yazarları (blogger), YouTuber'lar ve Instagram kullanıcıları gibi geniş bir yelpazeyi kapsamaktadır. Bu kişilerin, herhangi bir marka, ürün ya da hizmet hakkında yaptığı tavsiyeler, takipçilerinin satın alma davranışlarını doğrudan etkilemektedir. Influencerların takipçi profilleri genellikle sadık ve güven temellidir. Takipçiler, bu kişilerin paylaşımlarını güvenilir bulmakta ve onların deneyimlerinden yola çıkarak kendi yaşamlarına yön vermektedir (Canöz vd., 2020). Influencerlar genellikle iki temel grupta sınıflandırılmaktadır:

- Macro influencer: Resmî bir tanımı bulunmamakla birlikte, sosyal medya ortamında 100.000'in üzerinde takipçiye sahip ve fenomenleşmiş bireylerdir.
- Micro influencer: Belirli bir niş hedef kitleye hitap eden ve takipçi sayısı 100.000'in altında olan bireylerdir (Mahmutoğlu vd., 2018).

Günümüzde ürün çeşitliliğinin artması, tüketicilere daha fazla seçenek sunarken, satın alma karar sürecini de karmaşıklaştırmakta ve uzatmaktadır. Bu süreçte tüketicinin karar verme sürecini kısaltan en önemli unsurlardan biri, ürün ya da hizmete duyulan **güvendir**. Güven, bireyin marka ya da ürüne olan bağlılığını artıran kritik bir faktördür. Özellikle markaların güven temelli yaklaşımları, marka algısını pozitif yönde etkilemekte ve marka sadakati oluşturmada belirleyici olmaktadır. Tüketicinin, markanın niyetinden ve güvenilirliğinden emin olması durumu olarak tanımlanan marka güveni, müşteri memnuniyeti ve kalite sürekliliği açısından da büyük önem taşımaktadır (Tekin ve Tuğsal, 2019).

Reklam içerikleri, gelişen dijital teknolojilerle birlikte gündelik yaşamın hemen her alanında görünür hale gelmiştir. Ancak tüketiciler; kendilerini yansıtmayan, yaşam tarzlarıyla örtüşmeyen, somut fayda sunmayan reklamlara karşı giderek duyarsız hale gelmektedir. Bu nedenle, doğrudan pazarlama mesajlarının etkisi sorgulanmaya başlanmış ve markalar geleneksel reklam anlayışının ötesine geçme ihtiyacı duymuştur. Bu bağlamda, tüketicilerin güven duyduğu, deneyimlerini paylaşan bireylerin – yani influencerların – önemi artmıştır. Influencer marketing**,** markaların hedef kitleleriyle güven temelli bağ kurmasına olanak tanıyan

etkili bir pazarlama tekniği olarak öne çıkmaktadır. Günümüzün sosyal medya fenomenleri, geçmişin kanaat önderleri gibi, takipçileri üzerinde güven oluşturarak önemli bir etki alanı yaratmaktadır. Influencer marketing stratejisi, dijital tüketiciye dokunan, onunla etkileşim kurabilen, özgün ve pazarlanabilir içerik üretimi fikrine dayanmaktadır (Aktaş ve Şener, 2019). Influencerlar çekiliş düzenleme, yarışma yapma, firmalardan ücretsiz ürün alma ve bu ürünleri tanıtma, marka elçisi olma gibi farklı yöntemlerle ürün ve hizmet tanıtımı yapmaktadır. Ayrıca tanıtmakta oldukları ürünleri giyerek, kullanarak ya da tüketerek gündelik yaşamda da görünür kılmaktadırlar. Bunun yanında, diğer influencerlarla ya da ünlü kişilerle ortak projelerde yer alarak da takipçileri üzerinde pozitif ve yönlendirici bir etki oluşturmaktadırlar (Yalçın, 2024).

MATERYAL VE YÖNTEM

Bu çalışmada, nitel araştırma desenlerinden biri olan derinlemesine mülakat yöntemi kullanılmıştır. Araştırmanın amacı, influencerların Z kuşağı üzerindeki etkilerini çok boyutlu biçimde anlamlandırmak ve yorumlamaktır. Bu kapsamda, üniversite öğrencileri içinden seçilen 19 katılımcı ile mülakat gerçekleştirilmiştir. Katılımcılar, sosyal medyada aktif biçimde influencer içeriklerini takip eden ve bu içeriklerin satın alma davranışlarına etkisini değerlendirme yeterliliğine sahip bireylerden oluşmaktadır. Araştırma örneklemi, amaçlı örnekleme yöntemiyle belirlenmiş; farklı tüketim alışkanlıklarına ve sosyal medya kullanım düzeylerine sahip bireylerin görüşlerine ulaşılması hedeflenmiştir. Mülakat sürecinde katılımcılara; influencerlarla etkileşim düzeyleri, bu etkileşimin satın alma kararları üzerindeki etkisi ve influencerları bir kanaat önderi olarak görme nedenlerine ilişkin sorular yöneltilmiştir.

Veri toplama aracı olarak yarı yapılandırılmış mülakat formu kullanılmıştır. Mülakatlar hem yüz yüze hem de çevrim içi ortamlarda gerçekleştirilmiş; katılımcıların görüşlerini özgürce ifade edebilmeleri amacıyla açık uçlu sorulara yer verilmiştir. Elde edilen veriler**,** betimsel analiz yöntemiyle çözümlenmiştir. Analiz sürecinde, veriler tematik kodlama yoluyla gruplandırılmış ve influencerların Z kuşağı üzerindeki etkilerine ilişkin derinlemesine içgörüler elde edilmiştir. Böylece, dijital çağda kanaat önderliğinin tüketici davranışları üzerindeki etkisi çok yönlü değerlendirilmiştir.

Çalışmanın etik onay süreci Ankara Hacı Bayram Veli Üniversitesi Etik Komisyonu tarafından değerlendirilmiş ve 26.03.2025 tarihli, 341712 sayılı komisyon kararıyla, Araştırma Kod No: 2025/142 ile etik açıdan uygun bulunmuştur. Veri toplama süreci, etik ilkelere uygun olarak gerçekleştirilmiştir. Katılımcılara araştırmann amacı, süresi ve içerdiği haklar hakkında bilgilendirme yapılmış; görüşmeler öncesinde yazılı aydınlatılmış onam formları imzalatılmıştır. Katılım tamamen gönüllülük esasına dayanmış, kişisel bilgiler gizli tutulmuş ve tüm veriler anonimleştirilerek analiz edilmiştir. Araştırmanın örneklemini, farklı sosyoekonomik düzey, eğitim seviyesi ve okuma alışkanlıklarına sahip bireylerden oluşan heterojen bir grup oluşturmuştur. Tüm katılımcılar, 1997–2012 yılları arasında doğmuş bireylerden oluşan Z kuşağı mensuplarıdır. Katılım gönüllülük temelinde yürütülmüş ve katılımcılara diledikleri zaman görüşmeyi sonlandırabilecekleri açıkça belirtilmiştir.

Görüşmeler yüz yüze ve bire bir gerçekleştirilmiştir. Katılımcıların birbirinden veya üçüncü kişilerden etkilenme ihtimali ortadan kaldırılmıştır. Görüşme ortamları, katılımcıların kendilerini rahat ve güvende hissedecekleri sessiz ve özel alanlar olarak seçilmiştir. Görüşmelerde yarı yapılandırılmış soru formu kullanılmıştır. Verilerin derinliğini ve bütünlüğünü sağlamak amacıyla açık uçlu sorulara da yer verilmiştir.

BULGULAR

Bu bölümde, araştırma kapsamında görüşme yapılan 19 üniversite öğrencisine yöneltilen sorulara verilen yanıtlar analiz edilmiştir. Katılımcılara ilk olarak sosyal medya kullanım

sıklıkları ve tercih ettikleri platformlara ilişkin sorular yöneltilmiştir. Bu sorular aracılığıyla, Z kuşağı bireylerinin dijital ortamdaki davranış kalıplarını ve influencer içerikleriyle temas düzeylerini anlamak hedeflenmiştir.

Tablo 1. Katılımcıların Kullandıkları Sosyal Medya Platformları

Sosyal Medya Platformu	Sıklık (n)
TikTok	7
Instagram	4
Twitter/X	2
YouTube	2
Facebook	1
Pinterest	1
Snapchat	1
WhatsApp	1

Grafikte katılımcı yanıtlarında en fazla adı geçen sosyal medya platformları gösterilmektedir. Görüldüğü üzere TikTok olarak adlandırılan dijital mecra en çok tekrar eden platformdur.

Tablo 2. Katılımcıların Sosyal Medyaya Yönelik Olumsuz Geri Bildirimleri

Tema / Görüş	Sıklık (n)
Bağımlılık / Aşırı kullanım	9
Zaman kaybı / Kaybolma	6
Eleştiri / Bıkmışlık	4
Story paylaşma / Takıntı	2
Sadece mesajlaşma amacıyla kullanma	1
Sosyal medyayı hiç kullanmama	1
Algoritma etkisi	1

Öğrencilerin sosyal medya kullanımlarına ilişkin verdikleri yanıtlar, tematik analiz yöntemiyle kategorize edilmiştir. Elde edilen veriler doğrultusunda, en sık tekrar eden temaların bağımlılık ve aşırı kullanım olduğu görülmüştür. Bu bulgu, öğrencilerin sosyal medya ile kurdukları ilişkinin yoğun ve süreğen bir etkileşim biçimine dönüştüğünü göstermektedir. Bu durum, dijital mecraların Z kuşağının günlük yaşam pratiklerinde ne denli merkezi bir yere sahip olduğunu ortaya koymaktadır.

Katılımcılara yöneltilen bir diğer soru, “Takip ettiğiniz influencerlar kimlerdir ve onları neden takip ediyorsunuz?” şeklindedir. Bu soruya verilen yanıtlar, gençlerin influencer tercihlerini belirleyen başlıca faktörlerin anlaşılması açısından önem taşımaktadır. Elde edilen yanıtlar doğrultusunda, influencerların takip edilme nedenlerinin başında samimiyet**,** güvenilirlik**,** güncel içerik üretimi**,** eğlence değeri **ve** tarz/yaşam biçimiyle özdeşleşme gibi temaların öne çıktığı görülmektedir. Katılımcıların büyük bir kısmı, takip ettikleri influencerların kendileriyle benzer sosyal özellikler taşımasını ya da ulaşılabilir, “gerçek” bir yaşam tarzı sergilemesini etkileyici bulduklarını ifade etmiştir. Bu analiz, influencerların tüketim alışkanlıklarını, değer yargılarını ve kimlik inşasını etkileyen kültürel figürler olarak algılandığını göstermektedir.

Dolayısıyla, Z kuşağının dijital etkileşimler yoluyla kurduğu bağların, daha geniş sosyal ve kültürel çerçevede değerlendirilmesi gerekmektedir.

Tablo 3. Katılımcıların Takip Ettikleri Influencerlar ve Frekans Dağılımı

Influencer	Sıklık (n)	Frekans (%)
Danla Bilic	1	%5,6
Orkun Işıtmak	1	%5,6
Enes Batur	1	%5,6
Ece Targıt	1	%5,6
Barış Özcan	1	%5,6

Tablo 4. Influencer Takip Etme Nedenlerinin Tematik Dağılımı

Takip Sebebi	Sıklık (n)	Frekans (%)
Eğlenceli içerikler	7	%36,8
Güzellik/makyaj	4	%21,1
Moda/stil	3	%15,8
Bilgilendirici içerikler	2	%10,5
Sakinleştirici/ruh hali odaklı içerikler	2	%10,5
Spontane izleme (algoritma etkisi)	4	%21,1
Takip etmeyenler (güvensizlik)	2	%10,5

Katılımcıların büyük çoğunluğunun eğlence ve görselliğe dayalı içerikleri tercih ettiği görülmektedir. Bu durum influencer seçiminde samimiyet, içerik türü ve iletişim dili gibi faktörlerin belirleyici olduğunu ortaya koymaktadır. Özellikle Z kuşağı bireylerinin, takip ettikleri dijital figürlerle duygusal ve estetik düzeyde bir bağ kurma eğiliminde oldukları gözlemlenmektedir.

Satın alma öncesinde yapılan araştırmalar, tüketicilerin bilinç düzeyini ve karar verme süreçlerindeki seçicilik düzeyini ortaya koyması açısından önemli bir gösterge niteliğindedir. Bu bağlamda, influencer etkisine rağmen gençlerin araştırma eğilimleri, “Bir influencerın önerdiği bir ürünü almadan önce başka kaynaklardan ek araştırma yapar mısınız? Yapıyorsanız, hangi kriterlere dikkat edersiniz?” sorusu ile değerlendirilmiştir. Katılımcıların önemli bir kısmı, önerilen ürün hakkında ek bilgi edinme gereği duyduklarını belirtmiş; bu süreçte en çok dikkat ettikleri kriterler arasında ürün yorumları, kullanıcı deneyimleri, fiyat karşılaştırmaları ve marka güvenilirliği öne çıkmıştır.

Tablo 5. Katılımcıların Ürün Satın Almadan Önce Araştırma Yapma Durumları

Araştırma Durumu	Sıklık (n)	Frekans (%)
Araştırma yapanlar	15	%78,9
Araştırma yapmayanlar	4	%21,1

Tablo 6. Katılımcıların Kullandıkları Ürün Araştırma Yöntemleri

Araştırma Yöntemi	Sıklık (n)	Frekans (%)
Kullanıcı yorumları	9	%47,4
Fiyat karşılaştırması	6	%31,6
Diğer influencer görüşleri	4	%21,1
Video/test içerikleri	5	%26,3
Arkadaş tavsiyesi	2	%10,5

Influencer etkisine rağmen, katılımcıların büyük bir kısmı ürün hakkında ikinci kaynaklardan bilgi edinme gereği duyduklarını ifade etmiştir. Bu eğilim, genç tüketicilerin giderek daha bilinçli ve sorgulayıcı bir tüketim anlayışına yöneldiğini göstermektedir. Bilgiye farklı kaynaklardan ulaşma isteği öneriyi yapan influencera duyulan güvenin de sorgulandığını ortaya koymaktadır.

Katılımcılara, influencer önerisiyle gerçekleştirdikleri satın alma deneyimlerinin sonuçları sorulmuştur. “Influencerlardan gelen önerilere dayanarak yaptığınız bir satın alma deneyiminden memnun kalmadığınız oldu mu? Bu durum influencerlara olan güveninizi nasıl etkiledi?” sorusu influencerlara duyulan güven düzeyini değerlendirmeyi amaçlamaktadır. Deneyimlerin olumlu ya da olumsuz oluşu, tüketici davranışlarını doğrudan etkileyen belirleyici unsur olarak değerlendirilmektedir. Elde edilen veriler tüketicinin kişisel deneyim yoluyla influencera yönelik algısında değişiklikler yaşanabildiğini ve bu durumun gelecekteki satın alma kararlarını etkileyebileceğini göstermektedir.

Tablo 7. Influencer Önerisine Dayalı Satın Alma Deneyimleri ve Güven Algısı

Tema / Görüş	Sıklık (n)	Frekans (%)
Olumsuz deneyim yaşayanlar	15	%78,9
Hiç olumsuz deneyim yaşamayanlar	2	%10,5
Kararsız/karma görüş (suç tamamen influencerda değil)	2	%10,5
Güven kaybı yaşayanlar	7	%36,8
Daha temkinli yaklaşmaya başlayanlar	5	%26,3
Influencerı suçlamayan / anlayışla yaklaşanlar	4	%21,1
Sorunu satıcıya ya da ürüne bağlayanlar	3	%15,8

Katılımcıların büyük çoğunluğu, influencer önerisiyle gerçekleştirdikleri satın alma deneyiminden memnun kalmadıklarını ifade etmiştir. Bu olumsuz deneyimler genellikle influencera yönelik güven kaybı, daha temkinli bir yaklaşım geliştirme ve önerilere karşı eleştirel tutum takınma ile sonuçlanmıştır. Bazı katılımcılar yaşadıkları memnuniyetsizliği doğrudan influencera yüklememekte durumu ürün kaynaklı sorunlar, satıcıya bağlı eksiklikler ve/veya kişisel beklentilerle ilişkilendirerek değerlendirme yapmaktadır. Influencerı doğrudan suçlamayan ya da problemi öneren kişiden çok ürünün kendisine bağlayan bu katılımcılar, tüketici algısının bağlamsal ve çok katmanlı olduğunu ortaya koymaktadır. Bu bulgular, influencer güvenirliğinin tüketici değerlendirmelerinin mutlak bir yargıdan çok çeşitli etkenlere dayalı olarak şekillendiğini göstermektedir.

Katılımcılara yöneltilen "Influencerların sosyal medyadaki rolü hakkında eklemek istediğiniz başka bir görüşünüz var mı?" sorusu, bireylerin influencerlara dair genel kanaatlerini serbestçe ifade etmelerine olanak tanımaktadır. Bu açık uçlu soru katılımcıların kişisel gözlem ve deneyimlerini yansıtabilmeleri açısından önemli bir veri kaynağı oluşturmaktadır. Katılımcıların bir kısmı influencerları sosyal etki yaratan figürler, algı yöneticileri ya da gençler için rol model konumundaki bireyler olarak tanımlamıştır. Bu durum influencerların dijital kültürde üstlendikleri işlevin çok katmanlı ve dinamik bir yapıya sahip olduğunu ortaya koymaktadır. Görüşlerin çeşitliliği, influencer etkisinin sosyal ve kültürel boyutlarını kapsadığını göstermesi açısından dikkate değerdir.

Tablo 8. Katılımcıların Influencerların Sosyal Medyadaki Rolüne İlişkin Görüşleri

Tema / Görüş	Sıklık (n)	Frekans (%)
İçerik tekrarları / samimiyetsizlik / sıkıcılık	6	%31,6
Fazla etkili bulunmaları / rol model gibi algılanmaları	5	%26,3
Herkesin influencer olmaya çalışması / sıradanlaşma durumu	4	%21,1
Daha fazla sorumluluk taşımaları gerektiği görüşü	4	%21,1
Samimiyetin önemli olduğunu vurgulayanlar	3	%15,8
Olumlu ve ilham verici bulanlar	3	%15,8
Ekstra görüş belirtmeyen katılımcılar	3	%15,8

Elde edilen verilere göre katılımcıların bir bölümü influencer içerikleri tekrara düşmekte, paylaşımlarda samimiyetten uzaklaşılmakta ve zamanla sıkıcı bir hâl almaktadır. Bazı katılımcılar ise sosyal medyada herkesin influencer olmaya çalıştığını, bu durumun kavramın anlamını sıradanlaştırdığını ve etkisini azalttığını dile getirmiştir. Görüşler arasında samimiyetin hâlâ önemli bir kriter olarak öne çıktığı ancak bu niteliğin giderek zayıfladığına dair algının oluştuğu görülmektedir. Bu bulgular, influencerların sosyal medyadaki rollerinin eleştirel/olumlu açılardan çok boyutlu değerlendirildiğini ortaya koymaktadır.

Çalışmada influencerların ürün ve hizmet tanıtımlarının tüketiciler üzerindeki etkisi ele alınmıştır. Özellikle satın alma kararlarında influencerların oynadığı rol dikkat çekicidir. Satın alma davranışlarını şekillendiren etkenleri ortaya koymak amacıyla katılımcılara: "Bir influencerın önerdiği bir ürünü veya hizmeti satın aldığınız oldu mu? Olduysa, sizi en çok etkileyen faktör neydi?" sorusu yöneltilmiştir.

Tablo 9. Influencer Önerisiyle Ürün veya Hizmet Satın Alma Durumu

Durum	Sıklık (n)	Frekans (%)
Satın alanlar	15	%78,9
Satın almayanlar	4	%21,1

Tablo 10. Influencer Etkisiyle Satın Alma Nedenleri

Neden	Sıklık (n)	Frekans (%)
Güven / özenme	6	%31,6
Viral içerik etkisi	3	%15,8
Görsellik ve estetik	3	%15,8

Katılımcıların büyük çoğunluğu, influencer önerisiyle en az bir kez ürün veya hizmet satın aldıklarını ifade etmiştir. Ancak bu satın alma deneyimlerinin sonuçları, bireysel memnuniyet düzeylerine göre farklılık göstermektedir. Satın alma kararlarında en belirleyici faktörlerin başında influencerın güvenilir bulunması ve katılımcıların öneren kişiyle özdeşim kurması yer almaktadır. Bununla birlikte görsellik, estetik sunum ve popülerleşen içeriklerin etkisi gibi unsurlar da karar sürecinde etkili olmuştur. Satın alma davranışına yönelik motivasyonlar arasında özellikle güven/özenme teması öne çıkarken, görsel sunumun cazibesi ve içeriğin yaygınlığı da bazı katılımcıları etkilemiştir. Ancak satın alma sonrası yaşanan deneyimlere bakıldığında, memnuniyetsizlik yaşayan katılımcı sayısının memnun olanlardan fazla olduğu görülmektedir. Bazı katılımcılar üründen tamamen memnun kalırken, önemli bir kısmı beklentilerini karşılamayan ürün ve/veya hizmet nedeniyle pişmanlık yaşadığını belirtmiştir. Bu durum, influencer etkisinin satın alma davranışının başlatılmasında güçlü olmasına rağmen, sürdürülebilir memnuniyet açısından yeterli olmadığını göstermektedir.

Influencerlara karşı duyulan güven, takipçilerin içerik ve/veya ürünlere ilişkin tutumlarını doğrudan etkilemektedir. Çalışmada, katılımcıların influencer güvenilirliğine ilişkin algılarını değerlendirebilmek amacıyla, “Influencerların ürün veya hizmet tanıtımları yaparken ne kadar samimi ve güvenilir olduklarını düşünüyorsunuz?” sorusu yöneltilmiştir. Bu soru aracılığıyla duyulan güveni artıran ya da zedeleyen faktörler analiz edilmiştir.

Tablo 11. Katılımcıların Influencerlara Olan Güven Durumu

Güven Durumu	Sıklık (n)	Frekans (%)
Güvenmeyenler	13	%68,42
Duruma göre değişir diyenler	6	%31,6
Güvenenler	2	%10,5

Tablo 12. Güven Kaybına Yol Açan Faktörler

Faktör	Sıklık (n)	Frekans (%)
Abartılı anlatım / yapmacık üslup	9	%47,36
Ürünün birçok influencer tarafından aynı anda tanıtılması	4	%21,1
Ürünün gerçekten kullanılmadan tanıtılması	5	%26,3

Elde edilen veriler güven duygusunun influencer ve takipçi arasındaki etkileşimi yönlendiren temel dinamik olduğunu göstermektedir. Özellikle samimiyet algısı, ticari amaçla yapılan içeriklerde güvenin en sık sorgulanan boyutu olarak öne çıkmaktadır. Bununla birlikte şeffaflık,

sponsorlukların açıkça belirtilmesi ve influencerın daha önceki içeriklerle tutarlılığı gibi unsurlar güveni etkileyen önemli faktörler arasında yer almaktadır. Özellikle ürünün sunan kişi tarafından gerçekten kullanılıp kullanılmadığına dair şüpheler güveni zedeleyen başlıca unsurlar arasında sayılmaktadır. Bunun yanı sıra ürünün çok sayıda influencer tarafından eş zamanlı olarak tanıtılması içeriklerin özgünlüğüne ve samimiyetine dair soru işaretleri doğurmaktadır. Veriler influencer-takipçi ilişkisinde güvenin kırılgan bir yapıya sahip olduğunu ortaya koymaktadır.

Influencer içeriklerinde yer verdikleri sponsorluklar kullanıcıların içeriği algılayış biçimini değiştirebilmektedir. Çalışmada "lnfluencerların marka iş birlikleri ve sponsorluk anlaşmalarını nasıl değerlendiriyorsunuz? Bu tür içerikler satın alma kararınızı nasıl etkiliyor?" sorusu ile bu tür içeriklere yönelik tutumlar incelenmiştir.

Tablo 13. Influencer İçeriklerine Karşı Katılımcı Tutumları

Tutum	Sıklık (n)	Frekans (%)
Olumsuz etkilenme / içeriği atlama eğilimi	9	%47,36
Olumlu ya da nötr yaklaşanlar	7	%36,8
Farkında olmadan etkilendiğini belirtenler	3	%15,8

Katılımcıların büyük bir kısmı influencerların toplumsal meselelere yönelik içerik üretmesini önemli ve etkili bulmaktadır. Toplumsal konulara duyarlılık influencerların takipçileri üzerindeki algısal etkisi bakımından belirleyici aktör olarak öne çıkmaktadır. Özellikle çevre bilinci, kadın hakları, toplumsal cinsiyet eşitliği ve yardım kampanyalarına yönelik içerikler, olumlu ve samimi algılanmakta, bu tür içerikler influencerın güvenilirlik ve toplumsal sorumluluk algısını güçlendirmektedir. Bununla birlikte bu meseleleri önemsiz bulan ya da tarafsız kalan katılımcıların varlığı bu etki alanının homojen olmadığını göstermektedir. Ancak verilere bakıldığında katılımcıların influencerları sosyal bilinç oluşturabilecek aktörler olarak algılandıklarını söylemek mümkündür.

Tablo 14. Katılımcıların Influencerların Toplumsal Meselelere Yaklaşımına Yönelik

Tutum	Sıklık (n)	Frekans (%)
"Önemli" bulanlar	11	%57,89
"Etkiler" diyenler	5	%26,3
"Umursamıyorum" diyenler	3	%15

Influencer türüne göre değişen güven algısı, katılımcıların içerik tercihlerinde belirleyici bir unsur olarak öne çıkmaktadır. Bu bağlamda, mikro ve makro influencerlara duyulan güven karşılaştırmalı olarak ele alınmıştır.

Tablo 15. Katılımcıların Mikro ve Makro Influencerlara Yönelik Güven Algısı

Güvenilirlik Görüşü	Sıklık (n)	Frekans (%)
Mikro influencerlara güvenenler	13	%68,42
Fark olmadığını düşünenler	3	%15,8
Makro influencerları takip edenler	3	%15,8

Tablo 16. Mikro Influencerlara Duyulan Güvenin Gerekçeleri

Gerekçe	Sıklık (n)	Frekans (%)
Samimiyet / "bizden biri" hissi	7	%36,8
Soru-cevap etkileşimi	2	%10,5
Detaylı ve açıklayıcı anlatım	3	%15,8
Deneyim gibi paylaşım yapılması	4	%21,1

Mikro influencerlar daha küçük bir takipçi kitlesine sahip olmalarına rağmen içeriklerinde samimi, ulaşılabilir ve özgün bir tutum sergiledikleri için birçok katılımcı tarafından daha güvenilir bulunmuştur. Buna karşın makro influencerlar daha geniş kitlelere hitap etmektedir ancak içeriklerinin çoğunlukla sponsorluk temelli olması ve ürün/hizmeti profesyonel sunum biçimleri güven algısını zayıflatabilmektedir. Katılımcılar mikro influencerların ürün ve/veya hizmetleri gerçekten kullandığına inanma eğilimindeyken, makro influencerlara yönelik temkinli ve eleştirel bir bakış sergilemektedir. Bu durum katılımcıların içerik tercihlerini etkileyen temel faktörün içerik sunumundaki samimiyet, şeffaflık ve bireysel etkileşim düzeyi olduğunu göstermektedir.

Tüketicilerin hangi alanlarda influencerlardan etkilendiklerine ilişkin veriler pazarlama stratejilerinin oluşturulmasında önemli kaynak niteliği taşımaktadır. Bu kapsamda katılımcılara "Influencerların sizin fikirlerinizi veya yaşam tarzınızı etkilediğini düşünüyor musunuz? Eğer öyleyse, hangi alanlarda (örneğin moda, teknoloji, sağlık vb.) daha fazla etkili olduklarını düşünüyorsunuz?" sorusu yöneltilmiştir.

Tablo 17. Katılımcıların Influencerlardan Etkilenme Durumları

Etki Durumu	Sıklık (n)	Frekans (%)
Etkilendiğini belirtenler	15	%78,9
Bilinçsizce etkilendiğini düşünenler	3	%15,8
Etkilenmediğini belirtenler	2	%10,5

Tablo 18. Katılımcıların Influencerlardan Etkilendikleri Alanlar

Alan	Sıklık (n)	Frekans (%)
Moda / giyim	10	%52,63
Makyaj / cilt bakımı	6	%31,6
Teknoloji	5	%26,3
Tüketim alışkanlıkları	4	%21,1
Kişisel bakım	3	%15,8
Sağlık / beslenme	2	%10,5

Elde edilen bulgulara göre katılımcılar influencer etkisini en yoğun şekilde moda, makyaj ve teknoloji alanlarında hissettiklerini ifade etmiştir. Özellikle kişisel bakım, giyim tercihi ve teknolojik ürün seçimleri gibi günlük tüketim pratiklerinde influencerların yönlendirici rol

oynadığı görülmektedir. Bu durum dijital platformlarda içerik üreten kişilerin doğrudan tüketici davranışlarını şekillendiren etkili aktörler hâline geldiğini göstermektedir.

Katılımcılara yöneltilen "Sizce influencerların etkisi gelecekte nasıl bir yön izleyecek? Onların satın alma kararları ve tüketim alışkanlıkları üzerindeki gücü zamanla artacak mı, azalacak mı?" sorusu, influencer pazarlamasının geleceğine ilişkin algıları ve öngörüleri anlamayı amaçlamaktadır. Dijitalleşmenin hızla dönüştürdüğü medya ortamı bu tür etkilerin sürdürülebilirliği ve kalıcılığı konusunda farklı düşüncelerin oluşmasına zemin hazırlamaktadır. Bu doğrultuda katılımcılardan influencer etkisinin zamanla artıp artmayacağına dair kişisel tahminlerini paylaşmaları istenmiştir. Elde edilen veriler, dijital etkileşim biçimlerinin evrimi karşısında influencerların toplumsal/ekonomik etkilerinin nasıl algılandığını ortaya koymak açısından anlamlı sonuçlar sunmaktadır.

Tablo 19. Katılımcıların Influencer Etkisinin Geleceğine Yönelik Öngörüleri

Tema / Görüş	Sıklık (n)	Frekans (%)
Etkisi artar	8	%42,1
Etkisi azalır	7	%36,8
Etkisi platforma/teknolojiye göre değişir	5	%26,3
Etkisi sabit kalır veya biçim değiştirir	3	%15,8
"Herkes influencer olursa etkisi düşer" görüşü	3	%15,8

Katılımcıların influencer etkisinin geleceğine dair öngörüleri farklılık göstermektedir. Görüşler incelendiğinde büyük bir kısmı dijitalleşmenin etkisiyle influencerların daha da etkili hale geleceğini öne sürmektedir. Bununla birlikte önemli sayıda katılımcı influencer etkisinin zamanla azalacağını düşünmektedir. Bu düşüncenin gerekçeleri arasında, içeriklerin tekrara düşmesi, samimiyetin zayıflaması ve çok sayıda kişinin influencer olmaya çalışması nedeniyle oluşan "doğallık" sorunlarının öne çıktığı görülmektedir. Bir kısım katılımcı bu etkinin sabit kalabileceğini ya da zamanla içerik biçiminin değişebileceğini dile getirmiştir. Etkinin platform ve/veya teknolojik gelişmelere bağlı olarak değişkenlik göstereceğini düşündüğünü ifade eden bu katılımcılar algoritmaların yönlendirici rolüne dikkat çekmektedir. Elde edilen veriler influencer etkisinin geleceğine dair algıların çok boyutluluğunu ve bağlama duyarlığını ortaya koymaktadır.

SONUÇ

Bu araştırma, dijitalleşmenin yaşamın hemen her alanında bir dönüşüm gerçekleştirdiği çağdaş toplumda, Z kuşağının sosyal medya platformları aracılığıyla kurduğu etkileşim biçimlerini, gündelik yaşam pratiklerini ve bu etkileşimlerin tüketim davranışları üzerindeki yansımalarını incelemiştir. Özellikle influencerlar (sosyal medya fenomenleri), geleneksel medya figürlerinden farklı olarak daha kişisel, doğrudan ve samimi bir iletişim biçimi sergilemeleri nedeniyle, Z kuşağının tüketim kararlarında etkili kanaat önderleri haline gelmiştir. Araştırma bulguları, bu dönüşümün hem ekonomik hem kültürel boyutlarda analiz edilmesini zorunlu kılmaktadır.

Dijital dünyanın yerlisi şeklinde tanımlanan Z Kuşağı, teknolojik gelişmeleri hayatlarının merkezine alarak, bilgiye hızlı erişim sağlama, dijital araçlarla iletişim kurma ve sosyal medya platformları üzerinden toplumsal ilişkiler geliştirme konusunda oldukça yetkindir. Bu bağlamda sosyal medya, Z kuşağı için yalnızca bir sosyalleşme veya eğlence aracı değil; aynı

zamanda haber alma, bir bilgi edinme, dünyayı anlamlandırma ve tüketim kararlarını yönlendirme mecrası haline gelmiştir. Araştırma, influencerların paylaşıma sunduğu içeriklerin Z kuşağı üzerindeki yönlendirici etkisinin; içeriklerin biçimi, sunum tarzı ve içerik üreticisinin kişisel özellikleriyle doğrudan ilişkili olduğunu ortaya koymuştur.

Katılımcı gençlerle yapılan görüşmeler ve analizler neticesinde, influencerların tüketim kararlarını etkileyen çok yönlü figürler olduğu görülmüştür. Moda, güzellik, teknoloji, sağlık, yaşam tarzı ve eğlence gibi farklı temalarda içerik üreten influencerlar, takipçilerine sadece ürün veya hizmet tanıtmakla kalmamakta, aynı zamanda bu ürünlerin gündelik yaşamdaki yerini gösteren deneyimsel bir anlatı gerçekleştirmektedir. Bu deneyim aktarımı, geleneksel reklam modellerinden farklı olarak daha kişiselleştirilmiş ve güven temelli bir ilişki kurmaktadır. Katılımcıların büyük çoğunluğu, bir ürün veya hizmeti denemeden önce araştırma yaptığını, ilgili influencerların içeriklerini takip ettiğini, bu içeriklerden elde edilen izlenim doğrultusunda satın alma kararlarını şekillendirdiğini belirtmiştir.

Bu kapsamda influencerlara duyulan güvenin temel faktörleri; içeriklerdeki şeffaflık, sponsorlu paylaşımların açıkça belirtilmesi, ürünle ilgili olumlu-olumsuz tüm yönlerin samimi biçimde dile getirilmesi ve ilgili influencerın genel güvenilirliği olarak öne çıkmaktadır. Özellikle mikro influencerların, makro influencerlara kıyasla daha etkili bulunduğu tespit edilmiştir. Bunun temel nedeni, mikro influencerların takipçileriyle daha doğrudan, etkileşimli ve kişisel bir iletişim kurabilmeleri, böylelikle "samimi" bir imaj oluşturmalarıdır. Bu tür bir iletişim, izleyici üzerinde "bir arkadaş tavsiyesi" etkisi yaratmakta ve bu da satın alma kararlarını önemli ölçüde etkilemektedir.

Diğer taraftan, influencerlar hakkındaki eleştirel tutumlar da araştırmada dikkat çeken unsurlardandır. Katılımcıların bir bölümü, influencer içeriklerinde zamanla ortaya çıkan tekrarların, içerik üreticilerinin ticari kaygılarla hareket etmesinin ve markalarla kurulan işbirliklerinde samimiyetin azalmasının güven duygusunu zedelediğini ifade etmiştir. Bu bağlamda "influencer yorgunluğu" olarak adlandırılabilecek bir algı oluşmaya başladığı görülmektedir. Bu durum, influencer pazarlamasının sürdürülebilirliği açısından dikkatle değerlendirilmesi gereken önemli bir husustur. Katılımcıların bir kısmı, gelecekte influencer etkisinin daha da artacağını düşünmekle birlikte; bazı katılımcılar bu etkinin platformlara, algoritmalara, içerik biçimlerine ve sosyal eğilimlere bağlı olarak azalabileceğini öne sürmüştür. Özellikle Instagram gibi görsel ağırlıklı platformların gelecekteki işlevi, bu etkileşimin yönünü belirlemede etkili bir faktör olabilir.

Araştırmanın bir diğer dikkat çekici sonucu ise, sosyal sorumluluk merkezli içeriklerin Z kuşağı üzerinde olumlu bir etki oluşturmasıdır. Çevresel duyarlılık, hayvan hakları gibi temaları işleyen içerikler, sadece tüketime değil aynı zamanda bilinçli birey olma hâline de hitap etmektedir. Z kuşağı, yalnızca kaliteli veya trend olan ürünleri değil, aynı zamanda etik değerlere duyarlı markaları ve bu değerleri temsil eden influencerları da tercih etmektedir. Bu durum, influencerların sadece ekonomik değil aynı zamanda kültürel ve toplumsal anlamda da yön verici bir konumda ve sosyal bilinç oluşturma potansiyeline sahip aktörler olduğunu gözler önüne sermektedir.

Sonuç olarak, influencer pazarlaması, günümüzde geleneksel medya stratejilerinin ötesine geçen, çok boyutlu bir iletişim ve etkileşim modeli sunmaktadır. Z kuşağı üzerinde yalnızca ekonomik değil, aynı zamanda kültürel ve sosyal düzeyde de etkili bir araç haline gelmiştir. Onların dijital kimlikleriyle kurdukları ilişki, tüketici davranışlarını şekillendiren yeni parametreler doğurmuştur. Bu parametrelerin başında güven, deneyim, etkileşim, samimiyet ve toplumsal duyarlılık gibi değerler gelmektedir. Influencerlar, bu değerler üzerinden yeni nesil

bir kanaat önderliği modeli inşa etmekte ve geleneksel anlamda pasif tüketici konumundaki bireyleri, aktif karar vericilere dönüştürmektedir.

Bu dönüşüm, pazarlama dünyası açısından hem yeni fırsatlar hem de yeni sorumluluklar getirmektedir. Markaların influencer iş birliklerine yönelik daha etik, şeffaf ve hedef odaklı stratejiler geliştirmesi, yalnızca satış başarısını değil, aynı zamanda marka itibarı ve tüketici sadakatini de belirleyecek temel unsurlardan biri haline gelmiştir. Bu bağlamda influencer fenomeni, sadece geçici bir dijital trend değil; dijital çağın sosyal, kültürel ve ekonomik yapısının yeniden inşasında rol alan kalıcı bir aktör olarak değerlendirilebilir.

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QUALITATIVE ANALYSIS OF SECONDARY SCHOOL STUDENTS' PERCEPTIONS AND REFLECTIONS ON THEIR READING EXPERIENCES

ORTAOKUL ÖĞRENCİLERİNİN OKUMA DENEYİMLERİNE İLİŞKİN DUYGU VE DÜŞÜNCELERİNİN NİTEL ANALİZİ

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ÖZET

Okuma, temel dil becerilerinden biri olup bireylerin yalnızca bir metni seslendirmesi değil algılama ve anlama süreçlerinin de işe koşulduğu bir süreç olarak ifade edilebilir. Okul çağının başlamasıyla kazanılan okuma becerisi, kişinin okuma çabasına bağlı olarak zamanla gelişerek diğer temel becerilerden olan konuşma ve yazma alanlarının da gelişmesine katkı sağlar. Gelişen teknolojiyle birlikte dijital dünyada hızlı olmanın bireyi öne geçiren bir unsur haline gelmesiyle okuduğunu anlama süresinin de önem kazanmış olması dolaylı olarak okuma becerisinin de önemini arttırmaktadır. Bu araştırma, ortaokul öğrencilerinin okuma deneyimlerine ilişkin duygu ve düşüncelerini resimleri aracılığıyla nasıl ifade ettiklerini anlamak amacıyla yapılmıştır. Araştırmada nitel araştırma yöntemleri içinde yer alan doküman incelemesi yöntemi kullanılmıştır. Araştırmanın verileri Düzce'de 2024-2025 eğitim öğretim yılında bir ortaokulun 5, 6, 7 ve 8. sınıf kademelerinde öğrenim görmekte olan 72 öğrenciden toplanmıştır. Araştırma kapsamında, öğrencilerden okumanın onlara ne hissettirdiğini, onlar için ne anlama geldiğini resim çizme yoluyla aktarmaları ve resimleri bir cümle ile açıklamaları istenmiş olup çizilen resimler tematik analiz tekniği ile çözümlenmiştir. Araştırma sonucunda elde edilen bulgularda, öğrencilerin okuma deneyimlerine yönelik dört ana temaya ulaşılmış olup ulaşılan ana temalar "Olumlu Duygusal Deneyim, Gelişim ve Öğrenme, Eğlence ve Sosyal Boyut, Olumsuz Deneyimler" olarak ifade edilmiştir. Rahatlatıcı Etkiler ve Pozitif Duygular alt temalarından Olumlu Duygusal Deneyim temasına ulaşılmışken Zorlayıcı Faktörler ve Olumsuz Duygular alt temalarından Olumsuz Deneyimler temasına ulaşılmıştır. Yaşam Becerileri ve Zihinsel Süreçler alt temalarından Gelişim ve Öğrenme temasına ulaşılmış olup son olarak Sosyal Bağlantı ve Eğlence Unsurları alt temalarından da Eğlence ve Sosyal Boyut temasına ulaşılmıştır. Araştırma, öğrencilerin okuma deneyimlerine ilişkin çoğunlukla olumlu ve pozitif bir bakışa sahip olduklarını ancak azınlıkta olsalar da olumsuz bakışa sahip olan öğrencilerin de var olduğunu ortaya koymaktadır.

Anahtar Sözcükler: Okuma, Resim, Tematik Analiz.

Giriş

Okuma becerisi, bireylerin dinleme ve konuşma becerilerinden sonra çoğunlukla okul çağının başlamasıyla öğrendikleri temel dil becerilerinden biridir. Okul ortamında, öğretmen rehberliğinde sistematik bir şekilde öğrenilen bir beceri olan okuma, yalnızca bir metnin seslendirilmesi anlamına gelmeyip anlama ve algılama süreçlerinin de içinde yer aldığı bir faaliyettir.

İçinde yaşadığımız dünyayı algılama sürecinde okuma becerisi önemli bir yer tutmaktadır. Okuma, fiziksel ve bilişsel bileşenlerin oluşturduğu, karmaşık bir zihinsel süreçtir (Coşkun, 2002). Duyularımız aracılığıyla öğrendiklerimizin oranına bakıldığında %1'ini tatma, %1,5'ini dokunma, %3,5'ini koklama, %11'ini işitme, %83'ünü görme duyusuyla elde ettiğimiz görülmekte olup hem göze hem de kulağa hitap ettiği için okumanın öğrenme üzerinde %94 gibi önemli bir paya sahip olduğunu görmekteyiz (Aytaş, 2005). Okuma, yalnızca anadili anlama ve geliştirme sürecinde değil diğer alanlarda da kişinin kendini geliştirmesinde gerekli olan bir beceridir.

2000 yılından beri 15 yaşındaki öğrencilerin matematik, fen ve okuma alanlardaki becerilerini ölçen PISA tarafından yayınlanan 2022 raporuna göre Türkiye, okuma becerileri alanında 456 puanla katılan 81 ülke arasından 36 sıradayken 37 OECD ülkesi arasında ise 30.sıradadır (MEB, 2024). Ülke genelinde öğrencilerin okuduğunu anlama becerilerinin daha yüksek seviyeye çıkartabilmek adına öncelikle okuma becerisinin gelişememesinin ardında yatan nedenler öğrenilmelidir. Bu nedenleri öğrenebilmek için de öğrencilerde okuma becerisine yönelik hangi duygu ve düşüncelerin hâkim olduğunun bilinmesi gerekmektedir.

Alan yazında bu konu kapsamında, öğrencilerin okuma becerisine yönelik tutumlarının belirlenmesi amacıyla İşeri (2010), Ogurlu (2014), Akın (2016), Can, Deniz ve Çeçen (2016), Bayraktar (2017), Bayat ve Çetinkaya (2018), Şahin (2019), Bozoklu (2022) ve Yorgancı (2022) tarafından yapılan ve benzer şekilde olan birçok çalışma mevcuttur. Öğrencilerin çizmiş oldukları resimlerin analizi üzerine ise Çağlar (2017), Aktaş (2015), Atmaca ve Çelik (2024) ile Ersoy ve Türkkan (2009)'un yapmış oldukları çalışmalar bulunmaktadır ancak okuma becerisine yönelik böyle bir çalışmaya rastlanılmamış olması bu araştırmanın önemini arttırmaktadır.

Materyal ve Yöntem

Bu bölümde araştırmanın modeli, incelenen doküman, verilerin toplanması, verilerin analizi ve yorumlanması hakkında bilgi verilmiştir.

Araştırmanın Modeli

Ortaokul öğrencilerinin okuma deneyimlerine ilişkin duygu ve düşüncelerinin analiz edilmesini amaçlayan ve nitel şekilde desenlenen bu araştırmada doküman incelemesi yöntemi kullanılmıştır. "Doküman inceleme yöntemi, araştırmanın veri setini oluşturan birincil veya ikincil kaynak olarak nitelendirilen çeşitli dokümanların elde edilmesi, gözden geçirilmesi, sorgulanması ve analizi olarak tanımlanabilir" (Özkan, 2021, s. 2).

Çalışma Grubu ve İncelenen Doküman

Araştırmada 2024-2025 eğitim öğretim yılı içinde bir ortaokulda öğrenim görmekte olan 5, 6,7 ve 8.sınıf öğrencileri ile çalışılmıştır. Katılımcıların sınıf düzeyi ve cinsiyetlerine göre dağılımları Tablo 1'de sunulmuştur.

Tablo 1. Öğrencilerin Sınıf Düzeyine Göre Cinsiyet Dağılımları

	Cinsiyet	
Sınıf Düzeyi	**Kız *(f)***	**Erkek *(f)***
5.sınıf	11	8
6.sınıf	9	5
7.sınıf	12	6
8.sınıf	13	8
Toplam	**45**	**27**

Verilerin Toplanması

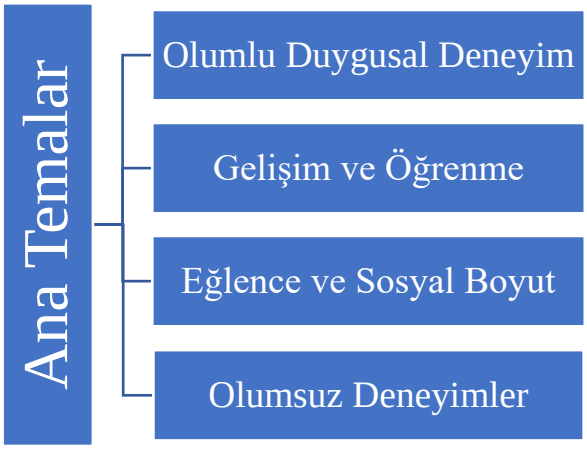
Araştırma kapsamında öğrencilerden okumanın onlara ne hissettirdiği, onlar için ne anlama geldiğini resim çizme yoluyla aktarmaları ve çizdikleri resimleri bir cümle ile açıklamaları istenmiştir. Öğrencilere resimlerini çizmeleri için bir ders saati süre tanınmıştır.

Verilerin Analizi ve Yorumlanması

Öğrencilerin çizdikleri resimler aracılığıyla toplanan veriler tematik analiz yöntemi kullanılarak analiz edilmiştir. "Tematik analiz, verilerdeki örüntüleri (temaları) belirleme, analiz etme ve raporlama için kullanılan bir yöntemdir. Tematik analiz, veri setinizi en küçük boyutlarda düzenlemenizi ve derinlemesine (zengin) betimlemenizi sağlar" (Braun ve Clarke, 2019, s. 875). Araştırma kapsamında incelenen resimler R1, R2, R3… şeklinde kodlanmıştır.

Bulgular ve Tartışma

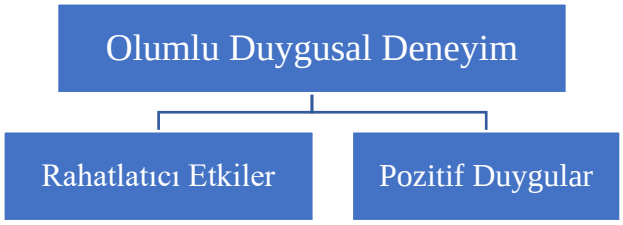
Ortaokul öğrencilerinin okuma deneyimlerine ilişkin duygu ve düşüncelerini ortaya koymayı amaçlayan bu araştırmada yapılan tematik analiz ve doküman incelemesi sonucunda ulaşılan ana temalar Şekil 1'de gösterilmiştir.



Şekil 1. Analiz Sonucunda Elde Edilen Ana Temalar

1.Olumlu Duygusal Deneyim

Olumlu Duygusal Deneyim temasına belirlenen iki ayrı alt tema ile ulaşılmıştır.



Şekil 2. Olumlu Duygusal Deneyim Ana Temasının Alt Temaları

1.1.Rahatlatıcı Etkiler

Tablo 2. Rahatlatıcı Etkiler Temasının Kodları

Rahatlatıcı Etkiler	
Kodlar	Resim Numaraları
Rahatlatıcı	R15
Huzur	R17, R19, R27, R33, R41, R47, R60, R68
His	R57, R61, R70
Şifa	R63

Rahatlatıcı koduna bakıldığında öğrencinin okuma deneyimleri hakkında duygu ve düşüncelerinin onları hayatta karşılaştıkları sıkıntılardan, sorunlardan ve stresten uzak tutan bir unsur olarak görülmüştür.



R15-Rahatlatıcı

Huzur koduna bakıldığında öğrencilerin okuma eylemini kendilerini bulutların üzerindeymiş gibi ya da baktıkça insanı rahatlatan, yeşil ve mavi tonların ağırlıkta olduğu bir manzara tablosuna bakıyormuş gibi hissettirdiği görülmüştür.



R60-Huzur



R68-Huzur

His koduna bakıldığında öğrencilerin okumayı duyguların bir yansıması ve kendilerini duygudan duyguya sürükleyen bir eylem olarak tasvir ettiği görülmüştür.



R61-His



R70-His

Şifa kodunda ise okuma eylemi öğrenci tarafından yaralarımızı daha hızlı iyileşmesi için sardığımız bir yara bandı ile özdeşleştirilmiş olduğu görülmektedir.



R63-Şifa

1.2. Pozitif Duygular

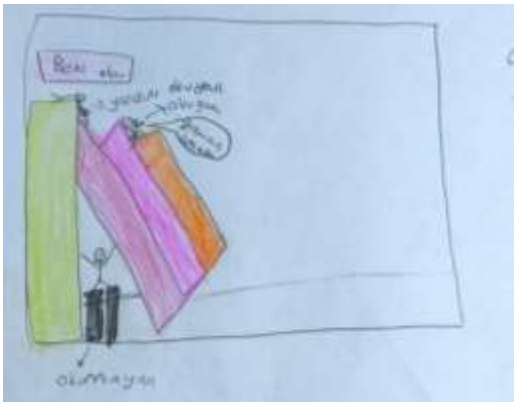
Tablo 3. Pozitif Duygular Temasının Kodları

Pozitif Duygular	
Kodlar	Resim Numaraları
Sevgi	R2, R4, R7, R10, R12, R46
Melodi	R5
Mutluluk	R8, R13, R18, R26, R28, R35, R42, R64
Umut	R9, R25, R69
Kurtarıcı	R11
Heyecan	R14, R16, R24, R30, R32

Sevgi koduna bakıldığında öğrencilerin okumaya karşı olan duygu ve düşüncelerinin kalpler aracılığıyla ve öğrencilerin yaparken keyif aldıkları bir eylem olarak ifade edilmiştir. Kurtarıcı kodunda öğrenci hayatta karşılaştığı zorlukları bir suya, okuma eylemini ise kendisini o suya batmaktan kurtaran bir unsur olarak resmetmiştir.



R10-Sevgi

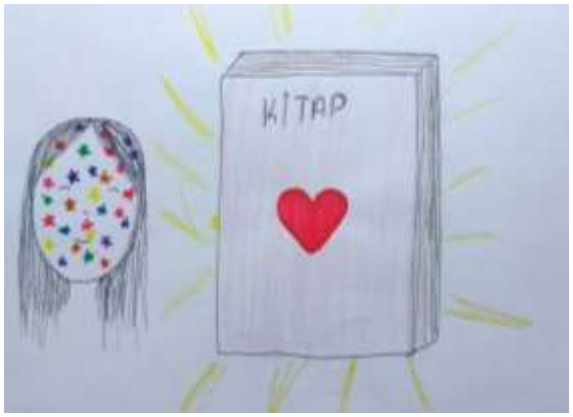


R11-Kurtarıcı

Melodi kodunda "Kitap Dünyası "adı verilen bir evrenin yaratıldığı resim görülmektedir. Bu evrende kitaplardan çıkan her sözcük hem öğrenci hem güneş hem de bulutlar için bir şarkı sözü olarak algıladığı görülmektedir. Mutluluk kodunda ise öğrencilerin okuma eyleminin kendilerine olumlu duygular verdiğini ve zihinlerinde mutluluk kavramıyla eşleştirdikleri görülmektedir.



R5-Melodi



R28-Mutluluk

Umut, insanı yaşama bağlayan bir unsurdur. Bu kodda öğrencilerin okuma eyleminin kendilerine yeni ufuklar açan ve hayat bağlanmalarını sağlayan renkli kapılar ile eşleştirildiği görülmektedir. Heyecan kodunda ise öğrencilerin, okumanın kendilerine heyecan veren bir eylem olduğunu ifade ettikleri görülmüştür.



R9- Umut



R14-Heyecan

2.Gelişim ve Öğrenme

Gelişim ve Öğrenme temasına belirlenen iki ayrı alt tema ile ulaşılmıştır.



Şekil 3. Gelişim ve Öğrenme Ana Temasının Alt Temaları

2.1.Yaşam Becerileri

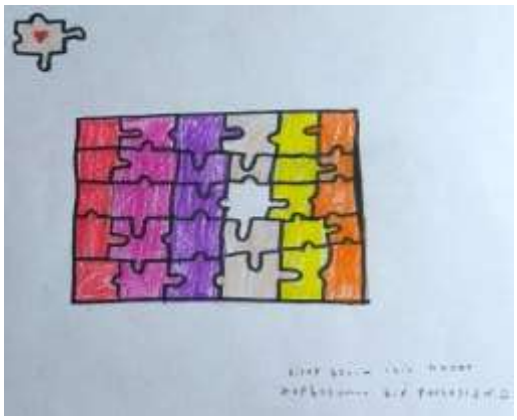
Tablo 4. Yaşam Becerileri Temasının Kodları

Yaşam Becerileri	
Kodlar	Resim Numaraları
Hayatın Merkezi	R21, R31, R48, R66
Hayatın Şifresi	R34
İyi Alternatif	R40

Hayatın Merkezi kodunda öğrenciler, okuma eylemini yaşamın tam merkezine yerleştirerek hayatlarında vazgeçilmez bir unsur olduğunu ifade etmiştir. Hatta yaşamımızı devam ettirebilmek için ihtiyaç duyduğumuz su ile özdeşleştirerek önemini vurgulamışlardır.

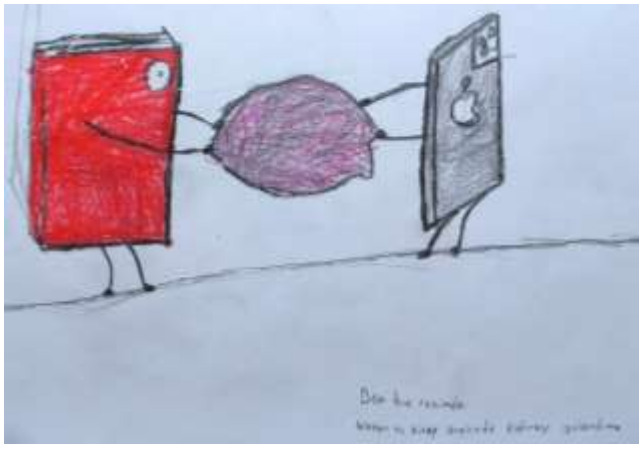


R31-Hayatın Merkezi

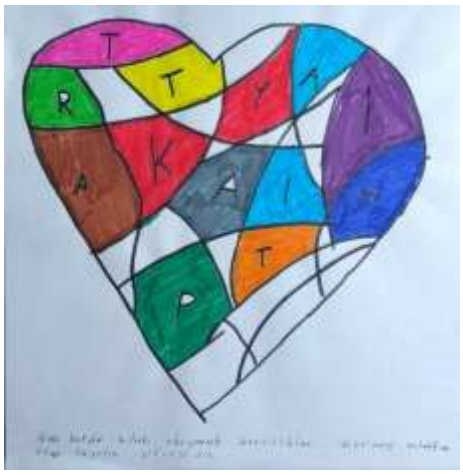


R48-Hayatın Merkezi

İyi Alternatif kodunda öğrencinin bir beyni çekiştiren kitap ve telefon resmettiği görülmektedir. Büyütülürken sıkça kendilerine zararlı olduğu belirtilen telefonun karşısına alternatif olarak kitabın yerleştirilmesi olumsuz bir unsura karşı iyi ve olumlu olan olarak ifade edilmiştir. Hayatın Şifresi kodunda ise öğrencinin okuma eylemini hayati organımız olan kalbin içine bir çeşit bulmaca koyarak ifade etmiş ve hayattaki karışıklıkları düzelten bir unsur olduğunu ifade etmiştir.



R40-İyi Alternatif



R34-Hayatın Şifresi

2.2.Zihinsel Süreçler

Tablo 5. Zihinsel Süreçler Temasının Kodları

Zihinsel Süreçler	
Kodlar	Resim Numaraları
Bilgilendirici	R6, R37, R38, R44, R45
Düşünme Gücü	R22
Hayal Gücü	R43

Bilgilendirici kodunda öğrenciler, okuma eylemini onlara bilmedikleri şeyi öğreten, öğrenmelerini sağlayan bir araç olarak tasvir etmişlerdir. Düşünme gücü kodunda ise öğrenci, okuma eylemi gerçekleşirken zihinde oluşan durumu çalışan bir mekanizmaya benzeterek okumanın zihni harekete geçirdiğini ifade etmiştir.



R38-Bilgilendirici

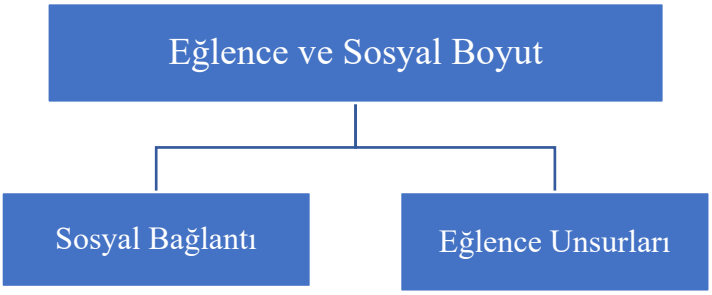


R22-Düşünme Gücü

Hayal gücü kodunda öğrenci, okuma eylemini hayal gücünü geliştiren bir unsur olarak tasvir etmiştir.

3. Eğlence ve Sosyal Boyut

Eğlence ve Sosyal Boyut temasına belirlenen iki ayrı alt tema ile ulaşılmıştır.



Şekil 4. Eğlence ve Sosyal Boyut Ana Temasının Alt Temaları

3.1. Sosyal Bağlantı

Tablo 6. Sosyal Bağlantı Temasının Kodları

Sosyal Bağlantı	
Kodlar	Resim Numaraları
En Yakın Arkadaş	R29, R51

Öğrenciler bu alt temada okuma eylemini, onları iyi anlayan ve yalnız kaldıklarında arkadaşlık yapan bir eylem olarak ifade etmişlerdir.



R29- En Yakın Arkadaş



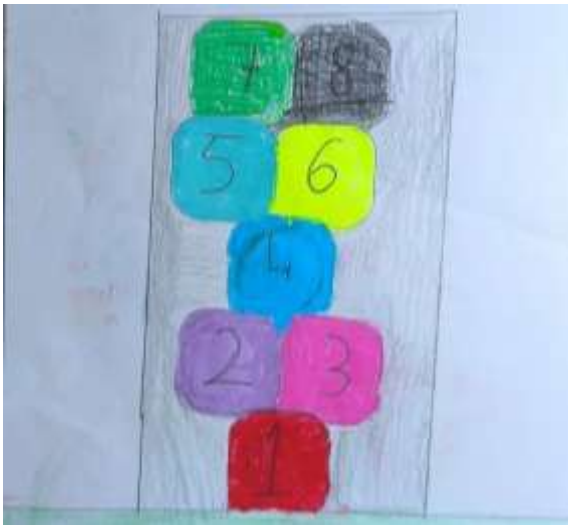
R51-En Yakın Arkadaş

3.2. Eğlence Unsurları

Tablo 7. Eğlence Unsurları Temasının Kodları

Eğlence Unsurları	
Kodlar	Resim Numaraları
Oyun	R3
Eğlence	R20, R23

Oyun kodunda okuma eylemi renkli bir seksek oyununa benzetilirken eğlence kodunda çocukların bulunmaktan çok keyif aldıkları park mekânı ile özdeşleştirilmiştir.



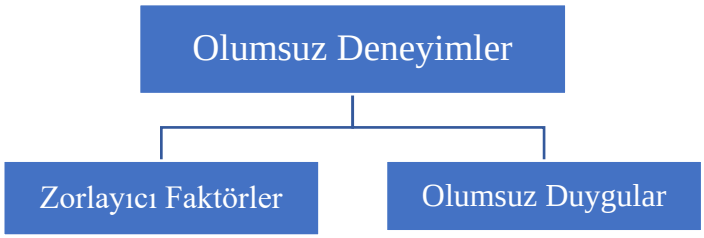
R3-Oyun



R23-Eğlence

4.Olumsuz Deneyimler

Olumsuz Deneyimler temasına belirlenen iki ayrı alt tema ile ulaşılmıştır.



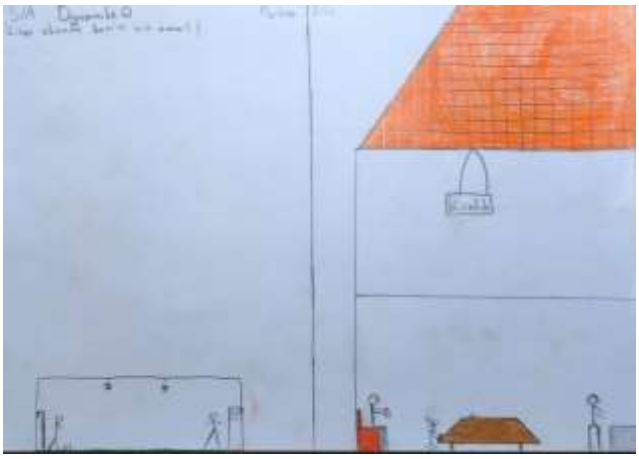
Şekil 5. Olumsuz Deneyimler Ana Temasının Alt Temaları

4.1. Zorlayıcı Faktörler

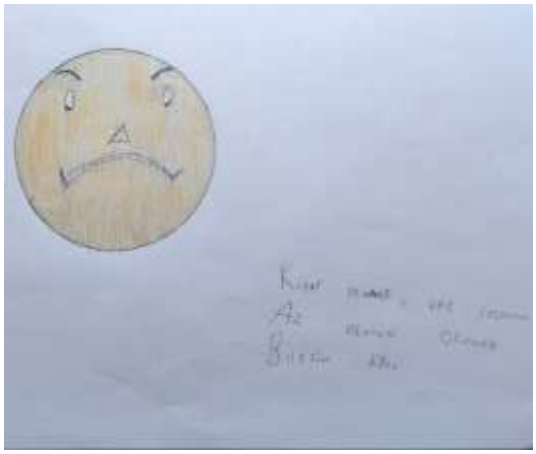
Tablo 8. Zorlayıcı Faktörler Temasının Kodları

Zorlayıcı Faktörler	
Kodlar	Resim Numaraları
Engel (oyun)	R1
Mecburiyet	R55
İkilem	R49, R58, R59, R62, R71

Engel kodunda öğrenci, okuma eyleminin kendisini dışarıdaki eğlenceden mahrum bırakan unsur olarak tasvir etmiş ve bundan dolayı zararlı olduğunu ifade etmiş. Mecburiyet kodunda ise okuma eylemini gerçekleştirmekten mutlu olmadığını ve öğrenmenin gerçekleşmesi için zorunlu olarak yapması gereken bir şey olarak tasvir etmiştir.

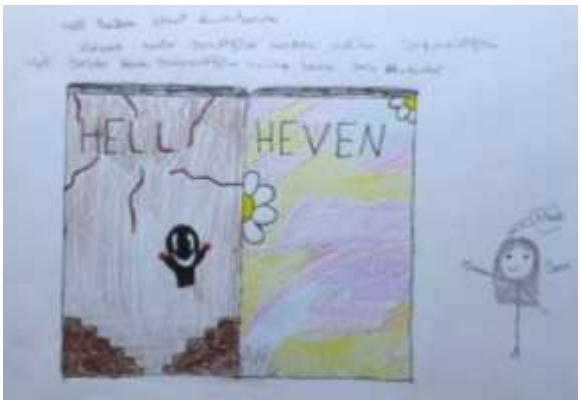


R1- Engel (Oyuna)



R55-Mecburiyet

İkilem kodunda öğrenciler okuma eylemi konusunda kararsız bir tutum sergilemişlerdir. İçerik ilgilerini çektiğinde sevdikleri bir eylemken hoşlarına gitmeyen bir ya da onları üzen bir şeyle karşılaştıklarında sevmedikleri bir eyleme dönüşmektedir.



R58-İkilem



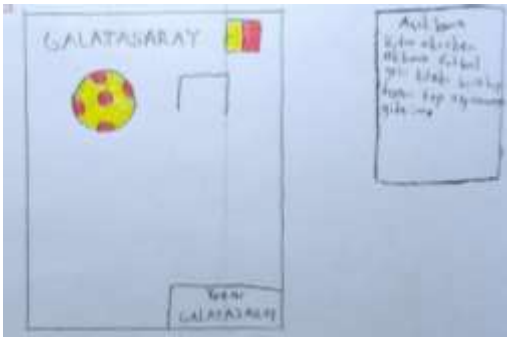
R62-İkilem

4.2. Olumsuz Duygular

Tablo 9. Olumsuz Duygular Temasının Kodları

Olumsuz Duygular	
Kodlar	Resim Numaraları
Sıkıcı Olması	R36, R39, R56, R65
Nefret	R50, R54, R67
Boşluk	R53, R72

Okuma eylemini sıkıcı bulan öğrenciler, okuma yaparken bunaldıklarını ve devam ettirme isteklerinin olmadığını, daha eğlenceli bir alternatif bulduklarında ona yöneldiklerini ifade etmişlerdir. Nefret kodunda ise öğrenciler, okuma eylemini zorla yaptıklarını ifade ederken kendilerini kurtarılması gereken bir şey yapıyormuş gibi tasvir etmişlerdir.



R39-Sıkıcı Olması



R50-Nefret

Boşluk kodunda öğrenciler, kitap okuma eyleminin kendileri için hiçbir anlam ifade etmediğini, zihinlerinde bu eyleme dair herhangi bir iz olmadığını belirtmişlerdir.



R53-Boşluk



R72-Boşluk

Sonuç ve Öneriler

Çalışma kapsamında elde edilen veriler ışığında, öğrencilerin çoğunluğunun okuma becerisine karşı duygu ve düşüncelerini pozitif, olumlu ve güzel olarak nitelendirdiği ancak okuma becerisine karşı negatif duygu ve düşüncelere sahip öğrencilerin de bulunduğu görülmüştür.

Öğrencilerin okuma becerisine yönelik duygu ve düşünceleri arasında en çok tekrar eden kavramlar rahatlatıcı etkiler alt teması başlığında bulunan huzur ile pozitif duygular alt teması başlığında bulunan mutluluk kavramıdır. Aynı zamanda bu iki kavram, öğrencilerin okumaya karşı bakış açıları arasında olumlu, pozitif ve güzel olarak nitelendirilebilecek Olumlu Duygusal Deneyim, Gelişim ve Öğrenme ile Eğlence ve Sosyal Boyut ana temaları arasında da en çok tekrar edilen kavramlardır. Okuma becerisine karşı daha negatif duygu ve düşüncelerin

temsil edildiği Olumsuz Deneyimler ana temasında ise en çok tekrar eden kavram zorlayıcı faktörler alt teması başlığı altında bulunan ikilem kavramı olmuştur.

Toplam yetmiş iki öğrenciden toplanan verilerden yirmi dört öğrenci ile en çok pozitif duygular alt temasının, iki öğrenci ile de en az sosyal bağlantı alt temasının tercih edildiği görülmüştür.

Elde edilen tüm bu sonuçlar öğrencilerin genelinin okumaya becerisini huzur ve mutluluk veren, bilgilendirici olan ve hayatın merkezinde yer alan bir beceri olarak algıladıklarını ve az sayıda da olsa okuma becerisini bir mecburiyet, vakit kaybı ve sıkıcı olarak gören ve okumadan nefret eden öğrencilerin de var olduğunu göstermektedir.

Öğrencilerin cinsiyetlerine göre okumaya karşı bakış açılarına bakıldığında olumlu duygu ve düşünceleri temsil eden ilk üç ana temada kız öğrencilerin çoğunlukta olduğu görülürken olumsuz duygu ve düşünceleri temsil eden son ana temasa ise çoğunluğu erkek öğrenciler oluşturmaktadır. Akın (2016), Bayraktar (2017) ve Bozoklu (2022)'nun da yapmış oldukları çalışmalarda kız öğrencilerin okumaya karşı duygu ve düşüncelerinin erkek öğrencilere göre daha pozitif yönde olduğu sonucuna ulaşılmıştır.

Okuma becerisine yönelik duygu ve düşüncelerini Olumsuz Deneyimler ana temasının kavramları ile açıklayan öğrencilerin çoğunluğunun erkek ve 8. sınıf seviyesinde öğrenim gördüğü ve aynı temanın kavramlarını kullanan kız öğrencilerin de 8. sınıf seviyesinde öğrenim gördükleri tespit edilmiştir. Bu sonuçlardan yola çıkılarak çalışma kapsamında öğrenim seviyesinin artmasıyla birlikte öğrencilerin okumaya karşı duygu ve düşüncelerin olumsuz yönde değiştiği görülmektedir. İşeri (2010), Yıldız (2013), Can, Çeçen ve Deniz (2016) ile Şahin (2019)'un yapmış oldukları çalışmalarda da benzer sonuçlara ulaşılmıştır.

Öğrencilerin eğitim hayatına başlamalarıyla birlikte sistemli bir şekilde öğrenilmeye başlanan okuma becerisine yönelik öğrencilerin duygu ve düşüncelerinin olumlu yönde seyretmesi ve okuma alışkanlığının kazandırılması için öğretmenlerin derslerini planlarken öğrencilerine gereken bilinci kazandıracak çalışmalara yer vermeleri önerilmektedir.

Diğer temel beceriler üzerine de öğrencilerin duygu ve düşüncelerini resim yoluyla analiz etmeye yönelik çalışmalar yapılabilir. Aynı zamanda elde edilen sonuçlardan yola çıkılarak öğrencilerin okumaya karşı olumsuz duygularının nedenlerinin araştırıldığı çalışmalar yapılabilir.

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SEPIC CONVERTER CIRCUITS DEVELOPMENT BOARD DESIGN IN LABORATORY TRAINING

LABORATUVAR EĞİTİMLERİNDE SEPİC KONVERTÖR DEVRELERİ GELİŞTİRME KARTI TASARIMI

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ÖZET

Öğrenmenin en etkili yöntemi, yaparak öğrenmedir. Teorik derslerin daha etkili öğrenilmesi için uygulamalı eğitim daha faydalı olacaktır. Mühendislik fakültelerinde verilen eğitimin kalıcı olabilmesi için bu öğretim yönteminin uygulanması gerekmektedir. Öğrenci, teorik bilgilerini simülasyon çalışmalarıyla riskleri ve maliyetleri azaltarak öğrenip, ardından üreteceği devre ile pratikte de pekiştirecektir. Güç elektroniği laboratuvar eğitimlerinde, öğrencilerin devre elemanlarının farklı değerlerini deneyebileceği devre kitlerinin geliştirilmesi önemlidir. Günümüzde, güç elektroniği laboratuvar eğitimlerinde genellikle hazır ve kapalı devre kitleri kullanılmaktadır. Bunun sonucunda, öğrenciler çoğu zaman yaptıkları deneylerin arka planındaki bilgilere ulaşamamakta, simülasyon çalışmaları ve devre tasarımlarını öğrenememektedir. Bu eksikliği gidermek için açık ve anlaşılır eğitim devre kitleri tasarlanmalı ve öğrencilere sunulmalıdır. Bu tez, güç elektroniği devreleri ve anahtarlamalı güç kaynakları eğitimi için temel topolojilerden biri olan SEPIC topolojisine odaklanmaktadır. Bu çalışmada geliştirilecek SEPIC devresi taşınabilir devre elemanlarına sahip olacaktır. Geliştirilen eğitim kitinde giriş voltajı 24V, çıkış voltajı ise 48V olacaktır. Öğrenciler, potansiyometreyi kullanarak doluluk oranı ve frekansını ayarlayabilecek ve farklı kondansatör ve bobinler arasından seçim yapabilecektir. Çıkış voltajındaki dalgalanmayı osiloskop ile gözlemleyebilecektir. Bu çalışma, elektronik devre tasarımı ve güç kaynağı üretimi konusunda önemli bir deneyim ve bilgi sağlayacaktır. Projeye ait değerlendirme ve geliştirme önerileri, gelecekteki çalışmalara değerli ipuçları sunmakta ve bu tür projelerin daha verimli ve güvenilir hale getirilmesine yönelik önemli adımlar içermektedir.

Anahtar Kelimeler: Sepic , güç elektroniği, eğitim kiti, uygulamalı öğrenme ve PWM

Giriş

Doğru akım–doğru akım (DC-DC) dönüştürücüler, herhangi bir doğru akım kaynağından alınan gerilimi artırma (boost) veya azaltma (buck) amacıyla kullanılan anahtarlamalı güç elektroniği devreleridir. Bu dönüştürücüler sayesinde hem sabit hem de değişken çıkış gerilimleri elde edilebilir. Gerilim regülasyonu ihtiyacına göre farklı topolojiler tercih edilmektedir. DC-DC dönüştürücüler genel olarak **yalıtımlı (isolated)** ve **yalıtımsız (non-isolated)** olmak üzere iki ana kategoriye ayrılır. Yalıtımlı dönüştürücüler, giriş ve çıkış arasındaki elektriksel bağlantıyı kesmek için genellikle transformatör yapıları kullanırken, yalıtımsız dönüştürücüler doğrudan bağlantıya sahiptir ve daha kompakt uygulamalar için tercih edilir. (Şeker, 2014).

Bu proje simülasyon çalışması akabinde güç elektroniği bilgisi ve laboratuvar da pratik becerisi kazandırarak, kullanıcıya elektronik sistemlerin tasarımı ve analizi konusundaki yetkinliklerini artırmayı amaçlamaktadır. (Çınar, 2019).

Bu çalışmanın amacı üniversitelerde eğitim gören mühendislik öğrencilerinin sepic konvertörü sadece teorik olarak değil deneysel çalışma içerisinde simüle edip akabinde uygulamasını yaparak teorideki bilgiyi daha iyi öğrenmesini amaçlamaktadır. Yaparak yaşayarak öğrenme beklenmektedir. Bu fikir mezun olduktan sonra mühendislik öğrencilerinin daha donanımlı ve pratik zekasını kullanabilen mühendislik öğrencileri yetiştirmeyi hedeflemektedir. Öğrenci sınavı geçmek için öğrendiği bilgiler mesleki hayatında onu büyük zorluklar yaşatacaktır.

Genelde bu ders üniversitelerde teorik okutulduğu için öğrenme gerçek mânada gerçekleşmemektedir. Bu tür faktörler nedeniyle bu çalışmanın önemi ortaya çıkmaktadır. Bu proje, katılımcıların elektronikle ilgili pratik bilgi edinmesini ve elektronik sistemleri tasarlayıp analiz etme becerilerini geliştirmesini amaçlamaktadır. (Akgül, Uçar, Öztürk & Ekşi, 2014).

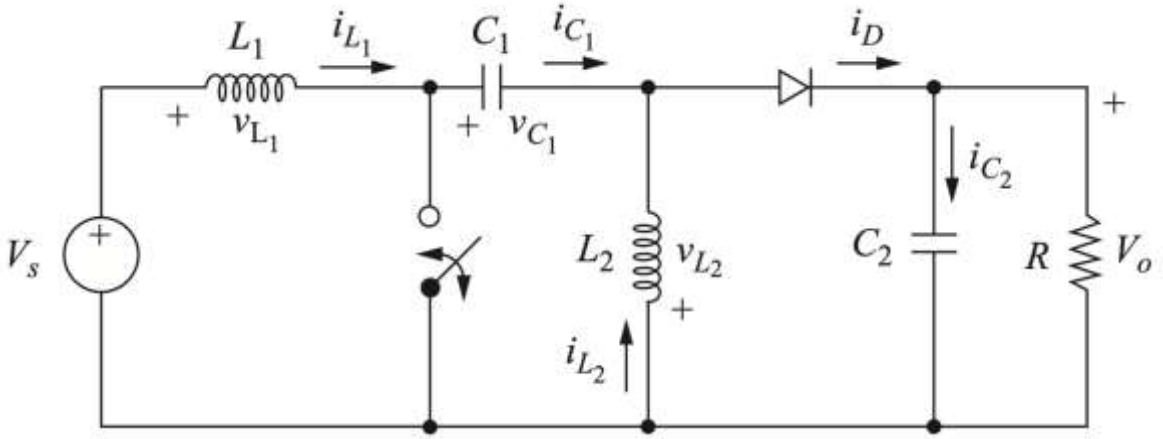
Materyal ve Yöntem

Adından da anlaşılacağı üzere, Tek Uçlu Birincil İndüktör Dönüştürücüsü (Single-Ended Primary Inductor Converter - SEPIC), giriş ve çıkış gerilimleri arasında aynı polariteyi koruyan ve gerilim seviyesini düşürme (buck), artırma (boost) ya da sabit tutma (buck-boost) işlevlerini yerine getirebilen, dördüncü dereceden bir anahtarlamalı güç dönüştürücüsüdür. Bu yapı, esnek gerilim regülasyonu gerektiren uygulamalarda yaygın olarak kullanılmakta olup, aynı zamanda çoklu çıkış konfigürasyonlarına genişletilebilme özelliğine sahiptir.

SEPIC topolojisinde çıkış gerilimi, ana anahtarlama elemanının görev döngüsü (duty cycle) ile doğrudan kontrol edilir. Bu kontrol mekanizması, dönüştürücünün çıkış voltajını girişten bağımsız olarak artırma, azaltma veya sabitleme yeteneğini mümkün kılar. Görev döngüsü oranı, sistemin çalışma koşullarına göre ayarlanarak istenilen çıkış gerilimi elde edilir.

SEPIC dönüştürücüler, %85'in üzerinde verimlilikle çalışabilmeleri sayesinde yüksek verimli enerji dönüşüm çözümleri sunar. Bu nedenle, özellikle batarya tabanlı sistemler, yenilenebilir enerji kaynakları ve taşınabilir elektronik cihazlar gibi enerji yönetimi açısından hassas uygulamalarda tercih edilmektedir. (Hart, 2010).

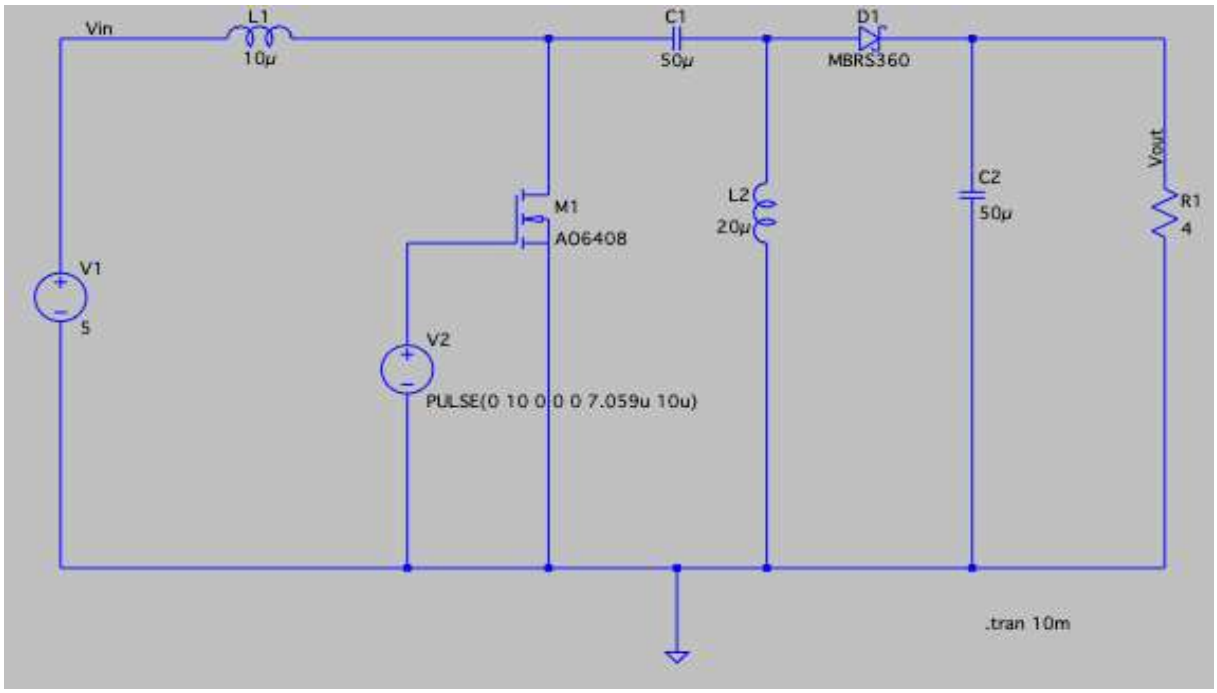
Sepic konvertör yani tek uçlu birincil indüktör dönüştürücü güç elektroniği alanında oldukça yaygın olarak kullanılmaktadır. Temel bir sepic dönüştürücü bir anahtarlama elemanı, entegre, bir diyot bir bobin ve bir kondansatörden oluşmaktadır. Temel bir sepic devresi verilmiştir. (Şekil 1)



Şekil 1. Temel Bir Sepic Dönüştürücü Devresi

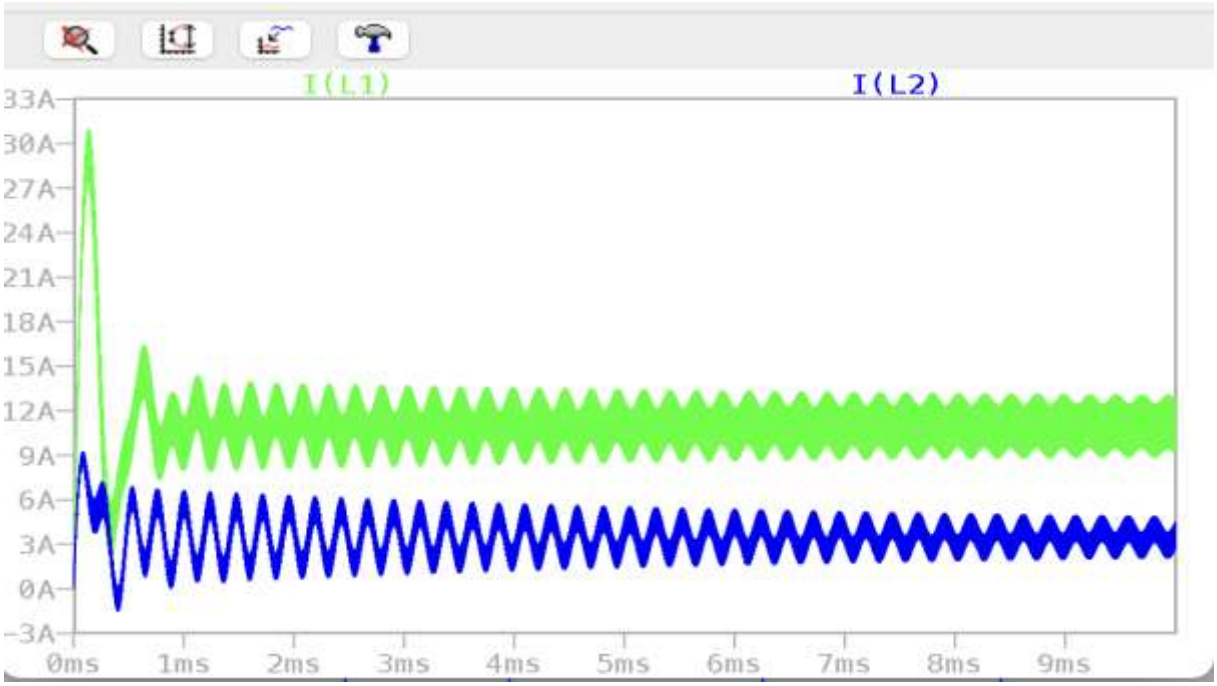
Bulgular ve Tartışma

Proje çalışmamızı gerçekleştirmeden önce olası riskleri ortadan kaldırmak ve maliyeti en aza indirmek için LTspice programı yardımı ile sepic devremizin şematik tasarımı yapılmıştır. (Şekil 2)



Şekil 2. LTspice Sepic Şematiği

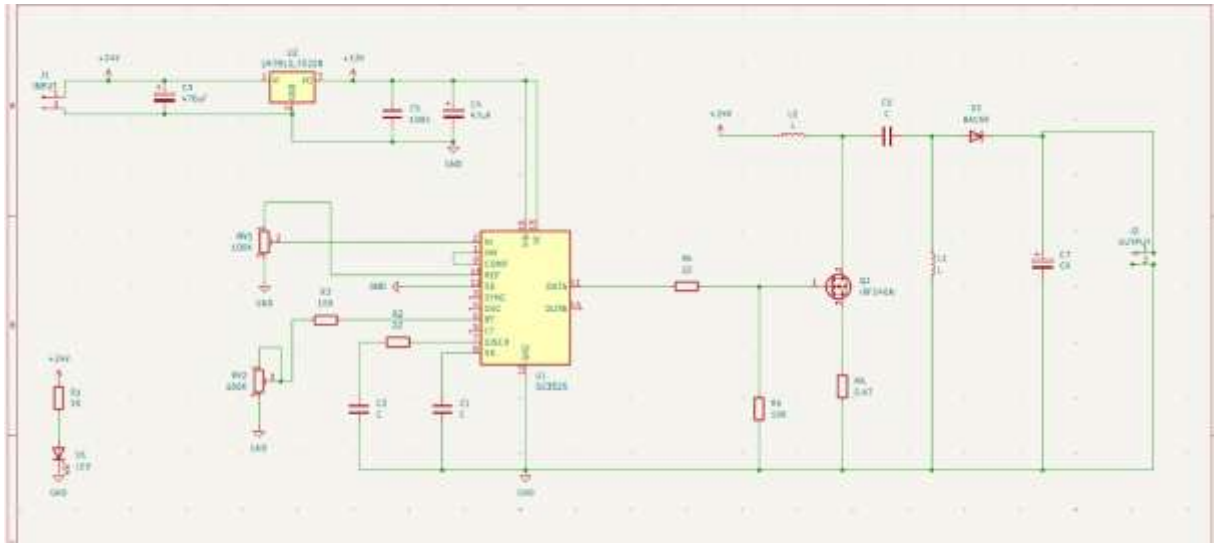
LtSpice programında sepic şematiği gerçekleştirilirken giriş gerilim değeri, L1 bobini, L2 bobini, C1 kondansatörü, C2 kondansatör değerlerine göre çıkışta beklediğimiz gerilim değerine uygun ve frekansı 0 ile 100kHz arası değerinde değiştirilebilen ve görev döngüsü ayarı yapılabilen bir LTspice şematiği yapılmıştır. Akabinde simülasyon sonuçları elde edilmiştir (Şekil 3).



Şekil 3. L1 ve L2 Akım Değerleri Grafiği

L1, girişe seri bağlı indüktör ; L2, Kapasitör (C1) aracılığıyla çıkış tarafına bağlı ikinci indüktördür. Yük direnci arttıkça çıkış akımı artar. Bu durumda L2' den geçen akım artar çünkü L2 doğrudan çıkışa bağlıdır. L1 MOSFET açıkken enerji depolar, kapandığında hem L2' ye hem de çıkışa enerji verir. Genelde L1 daha fazla akım taşır çünkü hem L2' ye hem de çıkışa enerji sağlar.

Sepic devremizin KiCad programı yardımı ile pcb tasarımı için şematiği gerçekleştirilmiştir. (Şekil 4)

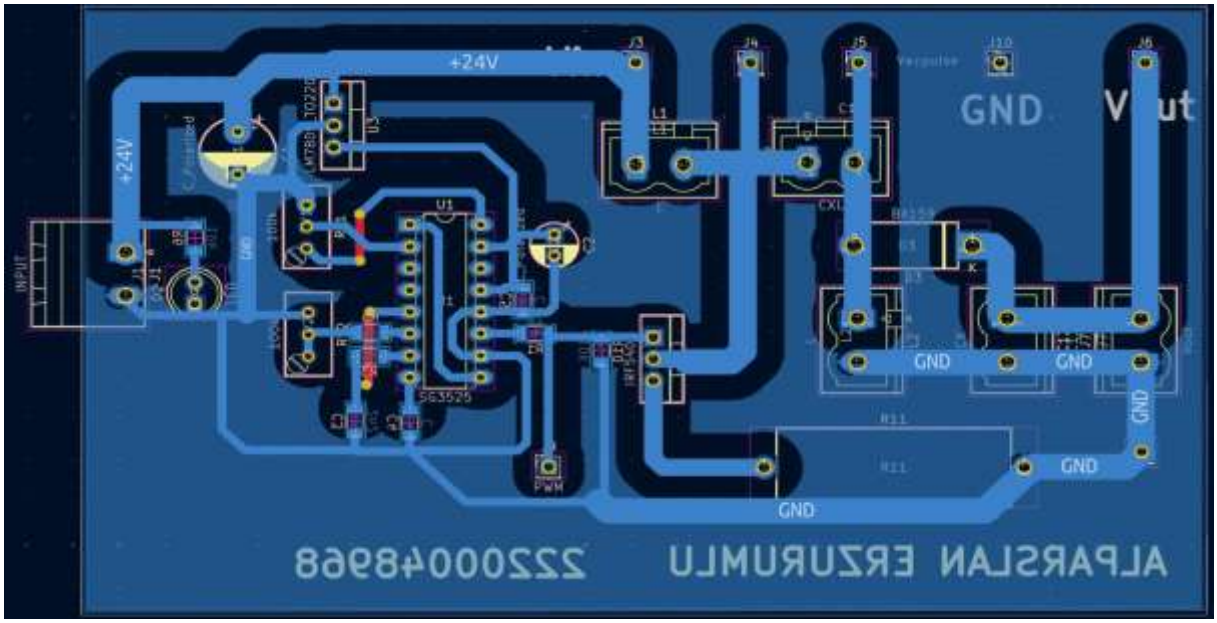


Şekil 4. KiCad Şematik Tasarımı Sepic

İlk enerjisini verdiğimiz zaman RC devresi ile belirlediğimiz frekans' da bir PWM sinyali üretir. Devremiz üzerinde bulunan iki trimpot ile ayrı ayrı frekans ve duty ayarı yapılabilir. PWM' in MOSFET' in gate ucuna gelmesi ile L1 üzerinde bulunan enerji mosfet üzerinden anahtarlanır.

SG3525’ in 12 volt’ ta sağlıklı beslenmesi ve en az ripple ile beslenmesi için 47 uF ile 100 n paralel bağlanmıştır.

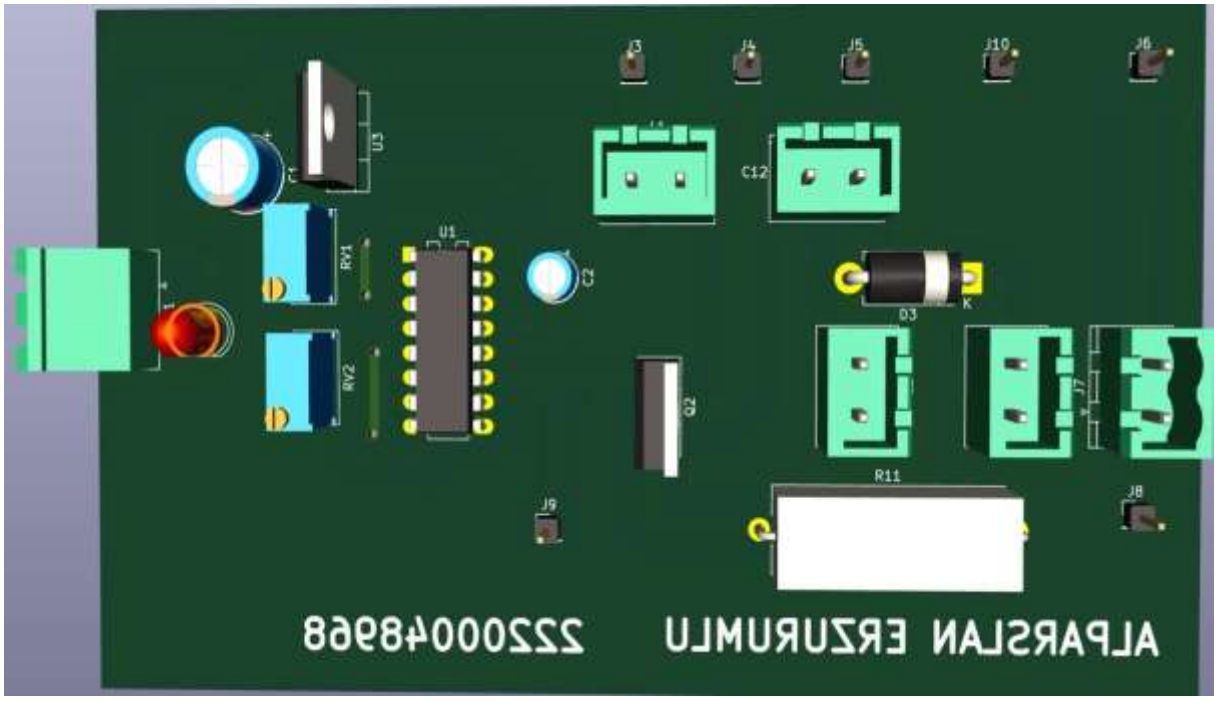
KiCad programı yardımıyla sepic pcb tasarımı yapılmıştır. (Şekil 5)



Şekil 5. KiCad PCB Tasarımı Sepic

LM7812 ile SG3525’ in stabil çalışması için gerekli olan voltajı yani gerilimi regüle eder. 24 voltluk girişi 12 volta sabitliyor.

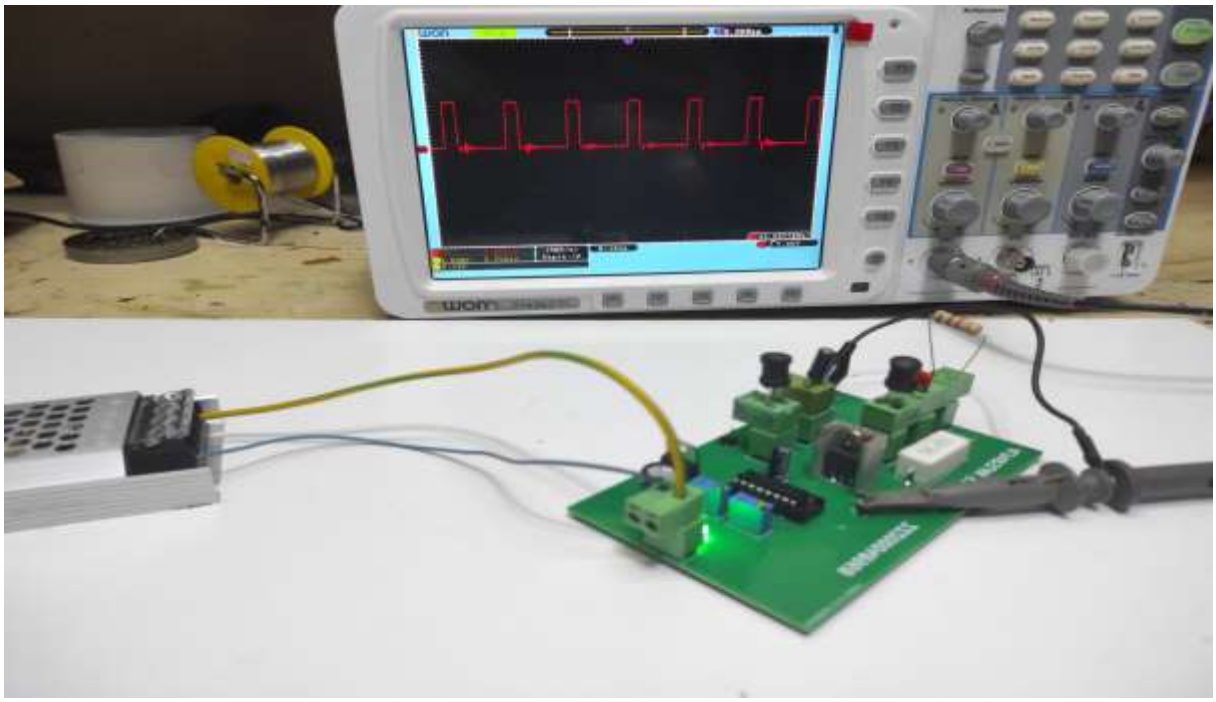
Sepic devremizin üç boyutlu tasarımı yapılmıştır. (Şekil 6)



Şekil 6. Sepic KiCad Programı ile Yapılan Pcb Üç Boyutlu Tasarımı

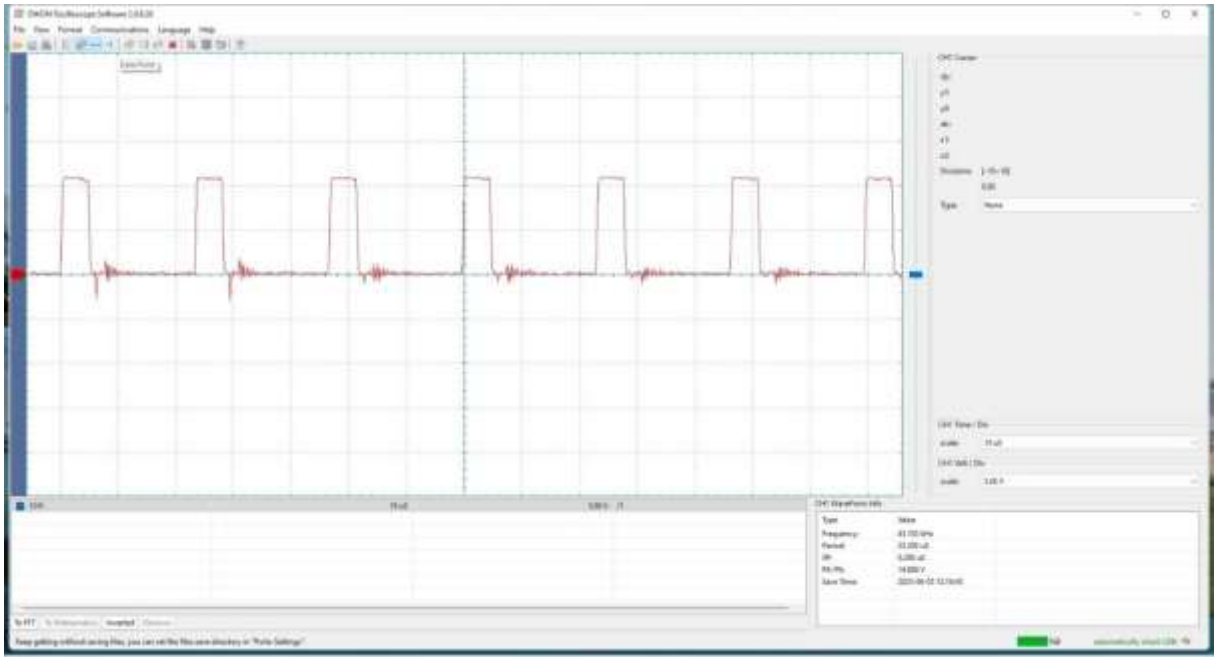
Sonuç ve Öneriler

Bu çalışma öğrencilerin farklı kondansatör ve bobin değerlerinin çıkış gerilimi, pulse değerinin ölçülebildiği bir güç kaynağı devresi eğitim kiti olarak hazırlanmıştır. Frekansı 43 KHz bobin değerleri 22 mh olan kondansatör değeri 0,47 uF ve 22k ohm' luk çıkış direnç değeri ile yapılmış olan sepic devremiz aşağıdaki gibi pwm pulse ölçümü gerçekleştirilmiştir. (Şekil 7)



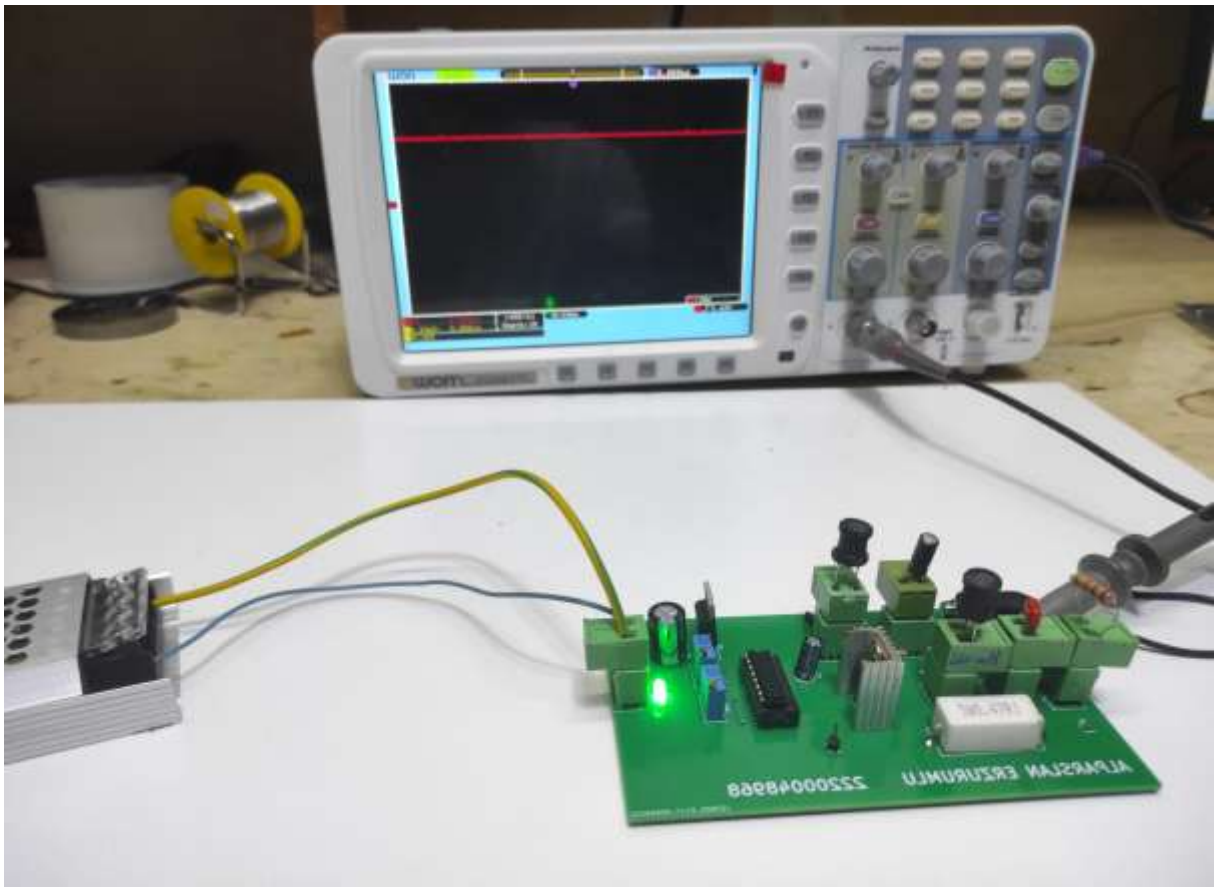
Şekil 7 Sepic Devresi 1 Pwm Pulse Ölçümü

Verilen devrenin pulse değeri dalga grafiği aşağıda osiloskop ekranında verilmiştir. (Şekil 8)



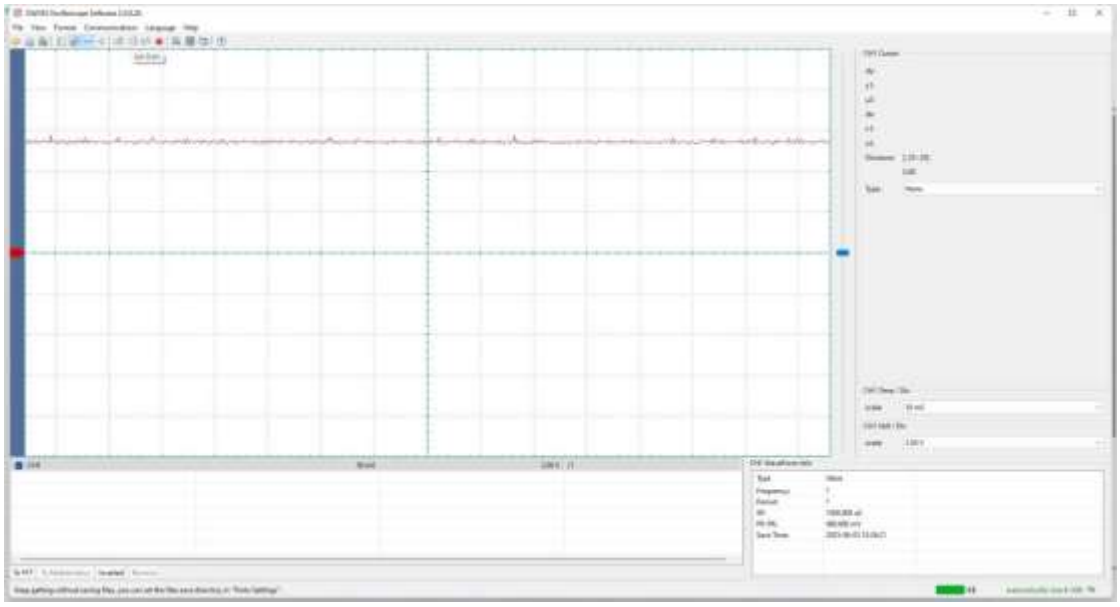
Şekil 8 Pwm Pulse Dalga Grafiği Osiloskop Görüntüsü 1

Tasarımı gerçekleştirilen sepic devremizin çıkış gerilimi ölçümü aşağıda verilmiştir. (Şekil 9)



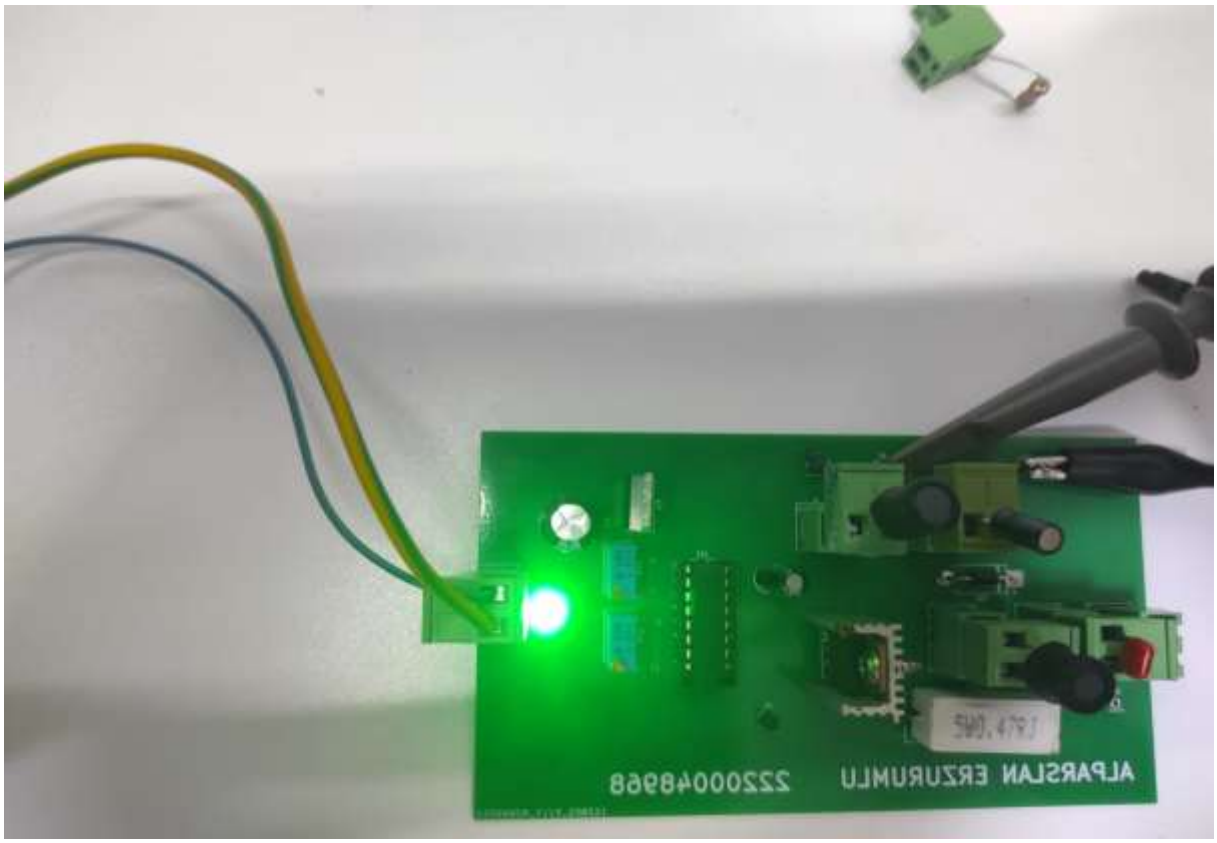
Şekil 9 Sepic Devresi Çıkış Gerilim Ölçümü

Çıkış gerilimi dalga grafiği osiloskop yardımı ile aşağıdaki verilmiştir. (Şekil 10)



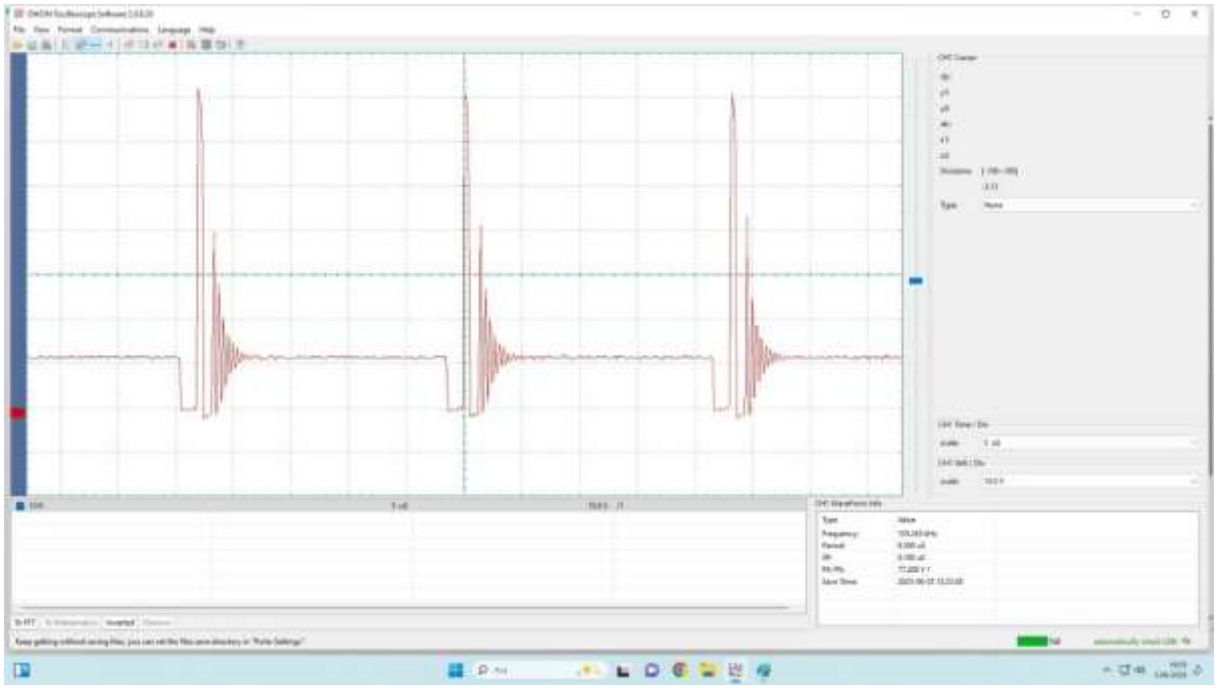
Şekil 10 Sepic Devresi Çıkış Gerilim Dalga Grafiği Osiloskop

Mosfet L1 C1 arası ölçümü ağaıdaki gibi gerçekleştirilmiştir. (Şekil 11)



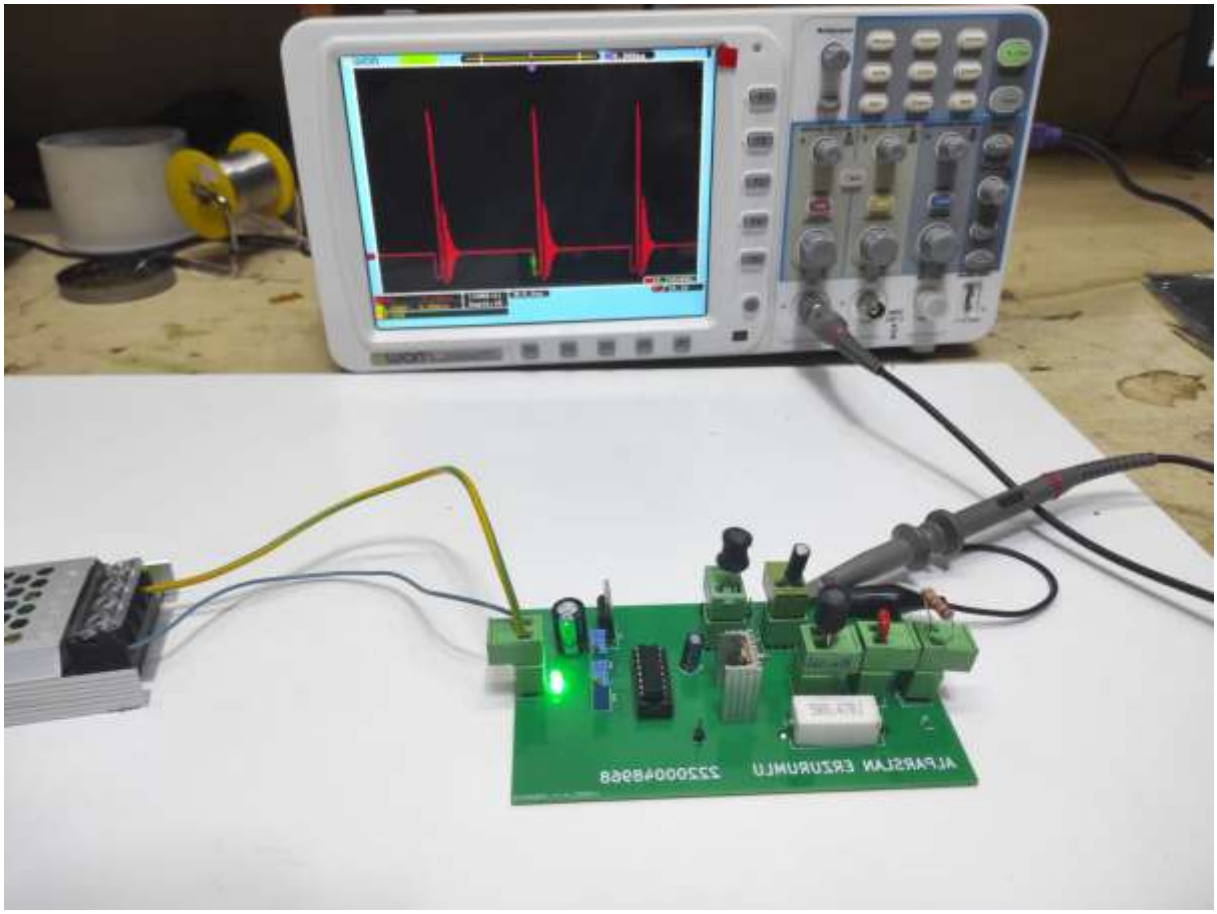
Şekil 11 Mosfet L1 ve C1 Arası Ölçüm

Mosfet L1 ve C1 arası ölçülen noktanın osiloskop ekranındaki dalga grafiği aşağıda verilmiştir. (Şekil 12)



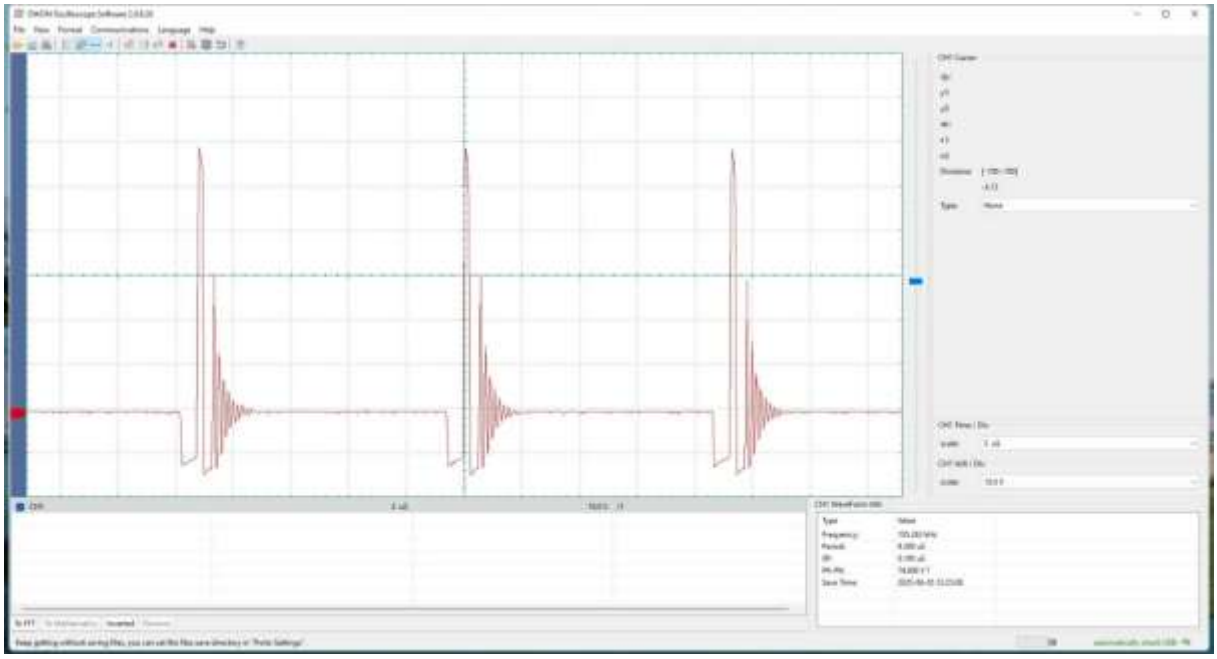
Şekil 12 Mosfet L1 ve L2 Arası Ölçümün Dalga Grafiği Osiloskop Görüntüsü

C1 ve L2 arası devremiz üzerinde yapılan ölçüm aşağıda verilmiştir. (Şekil 13)



Şekil 13 C1 ve L2 Arası Ölçüm

C1 ve L2 arası yapılan ölçümün osiloskop ekranındaki dalga grafiği verilmiştir. (Şekil 14)



Şekil 14 C1 ve L2 Arası Yapılan Ölçümün Osiloskop Ekranındaki Dalga grafiği

Teşekkür ve Bilgi Notu

Çalışmalarımızda Ahmet Serdar YILMAZ hocamıza çok teşekkür ediyoruz.

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Akgül, A., Uçar, M., Öztürk, M., & Ekşi, Z. (2014). Mühendislik eğitiminin iyileştirilmesine yönelik öneriler, geleceğin mühendisleri ve işgücü analizi. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *17*(1), 14–18. https://dergipark.org.tr/tr/pub/sdufenbed/issue/20800/222065https://dergipark.org.tr/tr/pub/sdufenbed/issue/20800/222065

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FLYBACK CIRCUITS DEVELOPMENT BOARD DESIGN IN LABORATORY TRAINING

LABORATUAR EĞİTİMİNDE FLYBACK DEVRELER GELİŞTİRME KARTI TASARIMI

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ÖZET

Laboratuvar uygulamaları, özellikle mühendislik disiplinlerinde, teknik eğitimin hayati bir parçasıdır. Uygulamalı deneyim olmadan teorik bilgi genellikle yüzeyde kalır ve öğrenciler üzerinde kalıcı bir etki bırakmaz. Hem bilgili hem de pratik açıdan yetkin mühendisler yetiştirebilmek için, teorik öğrenmeyi pratik uygulamalarla entegre eden bir eğitim metodolojisinin uygulanması gereklidir. Bu çalışma, Elektrik Mühendisliği müfredatında yer alan Güç Elektroniği dersi için öğrenci tarafından değiştirilebilir laboratuvar kitlerinin geliştirilmesinin önemini vurgulamaktadır. Mevcut laboratuvar sistemleri genellikle önceden monte edilmiş, kapalı sistemlere dayanmaktadır. Bu sistemler işlevsel olsalar da, öğrencilerin deney yaptıkları devrelerin iç yapısını ve teorik temelini tam anlamıyla kavramalarını engellemektedir. Bu nedenle, tasarım ve simülasyon gibi kritik süreçlerle etkileşime girme fırsatını kaçırmaktadırlar. Bu eğitimsel eksikliği gidermek amacıyla, çalışma açık, modüler ve kolay anlaşılır eğitim kitlerinin tasarım ve geliştirilmesini önermektedir. Projenin odağı, Güç Elektroniği ve anahtarlamalı güç kaynakları (SMPS) eğitiminde temel yapılardan biri olan Flyback dönüştürücü topolojisidir. Bu eğitim kiti, taşınabilir ve değiştirilebilir bileşenlere sahip bir Flyback dönüştürücü devresi içermektedir. Sistemin giriş voltajı 24V, çıkış voltajı ise 48V olarak belirlenmiştir. Öğrenciler; görev döngüsü, çıkış gerilimi dalgalanması ve anahtarlama frekansı gibi parametreleri seçilebilir bileşenler ve bir potansiyometre aracılığıyla ayarlayabilmektedir. Bu proje, hem teorik bilginin pekiştirilmesi hem de elektronik devre tasarımı ve güç kaynağı geliştirme konularında pratik becerilerin kazanılması açısından önemli katkılar sunmaktadır. Ayrıca çalışmada sunulan değerlendirme ve iyileştirme önerileri, benzer eğitim sistemlerinin daha etkili, erişilebilir ve güvenilir hale getirilmesi için gelecekteki araştırmalara değerli bir rehberlik sağlamaktadır.

Anahtar Kelimeler: Güç elektroniği, flyback dönüştürücü, eğitim kiti, anahtarlamalı güç kaynağı, voltaj dalgalanması

Giriş

DC-DC dönüştürücüler, herhangi bir DC kaynaktan aldığı gerilimi yükseltip düşürür. Sabit veya değişken gerilimler elde etmek için kullanılır. Bu dönüştürücüler yalıtımlı ve yalıtımsız olmak üzere iki grupta incelenir. (Şeker, 2014). Bu proje hem elektronik bilgisi hem de uygulama becerisi kazandırarak, katılımcıların elektronik sistemlerin tasarımı ve analizi konusundaki yetkinliklerini artırmayı amaçlamaktadır. (Çınar, 2019).

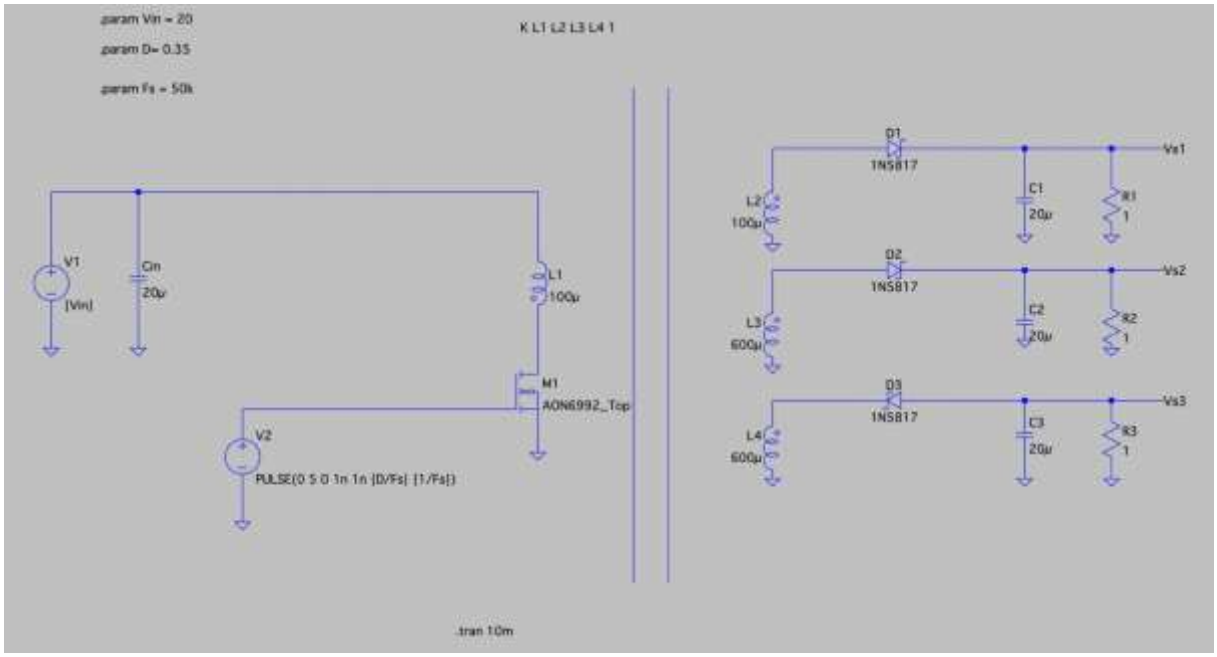
Bu elektronik proje, temel amaç olarak, bir güç kaynağı devresi oluşturmayı hedeflemektedir. Güç kaynağı devreleri, elektronik cihazların çalışması için gerekli olan doğru akım (DC) voltajını sağlamak amacıyla kullanılır. Bu projenin özel hedefi, belirli bir giriş voltajını alarak, istenilen çıkış voltajını stabil ve güvenilir bir şekilde sağlamaktır. Öğrenciler detaylı tasarım adımlarını takip ederek uygulama sonuçlarını da görebileceği, farklı trafo tasarımlarının devre çıkışın etkisini bu uygulama kartı ile kolaylıkla öğrenebileceği tek bir devre üzerinde sonuçlar alması hedeflenmektedir. Kısaca modüler olarak gerilim elde etmek, üretmek ya da akım modlu kontrol eğitimi için bu kart kullanılabilir olacaktır. Laboratuvar eğitimlerinde basitten karmaşığa doğru farklı sonuçlar alınmasının faydalı olacağı amaçlanmıştır. Bu elektronik devrenin çalışma prensibi ve fonksiyonları, temel elektrik ve elektronik kurallarına dayanarak, bileşenlerin birbiriyle nasıl etkileştiği ve işlev gördüğü üzerine kuruludur (Akgül, Uçar, Öztürk & Ekşi, 2014).

Materyal ve Yöntem

Flyback evirici çalışma yapısı, anahtarın iletim ve kesimde olması şeklinde değişkenlik gösterir (Göçer, 2024). Flyback dönüştürücüler girişine uygulanan değişik gerilimlerde çıkış gerilimini yükseltip düşürebilen bir sistemde çalışabilirler. (Hart, 2010).

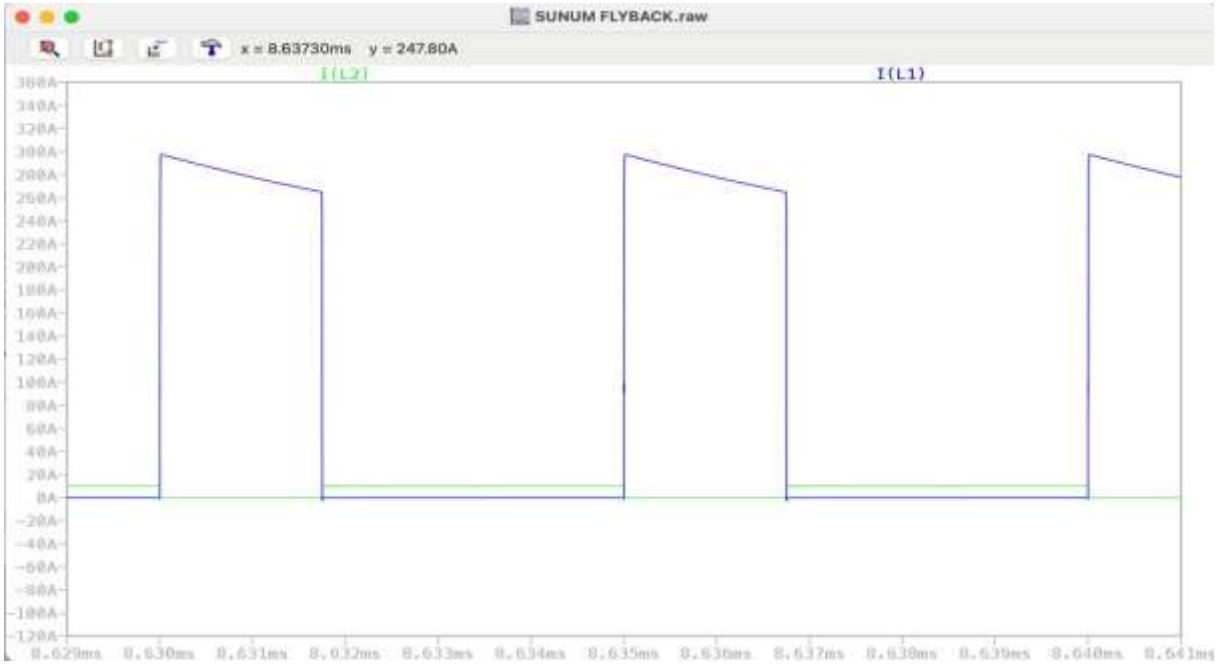
Bulgular ve Tartışma

Projenin test aşaması, devrenin doğru çalışıp çalışmadığını ve tasarım gereksinimlerini karşılayıp karşılamadığını doğrulamak için titizlikle yürütülmüştür. Öncelikle flyback dönüştürücünün LTspice programı ile benzetim çalışması yapılmıştır.



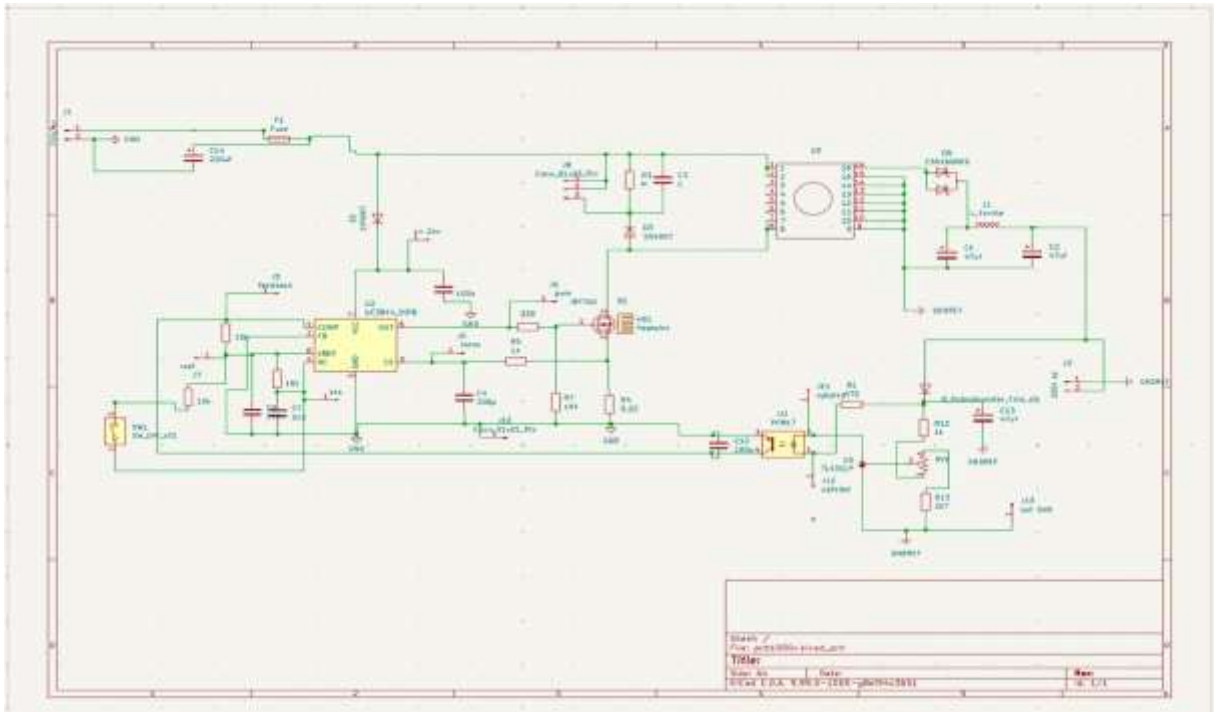
Şekil 1. LTspice Flyback Şematiği

LtSpice programında flyback şematiği gerçekleştirilirken giriş gerilim değeri, L1 bobini, L2 bobini, C1 kondansatörü, C2 kondansatör değerlerine göre çıkışta beklediğimiz gerilim değerine uygun ve frekansı 50kHz değerinde ve görev döngüsü ayarı yapılabilen bir LTspice şematiği yapılmıştır. Akabinde simülasyon sonuçları elde edilmiştir (Şekil 2).



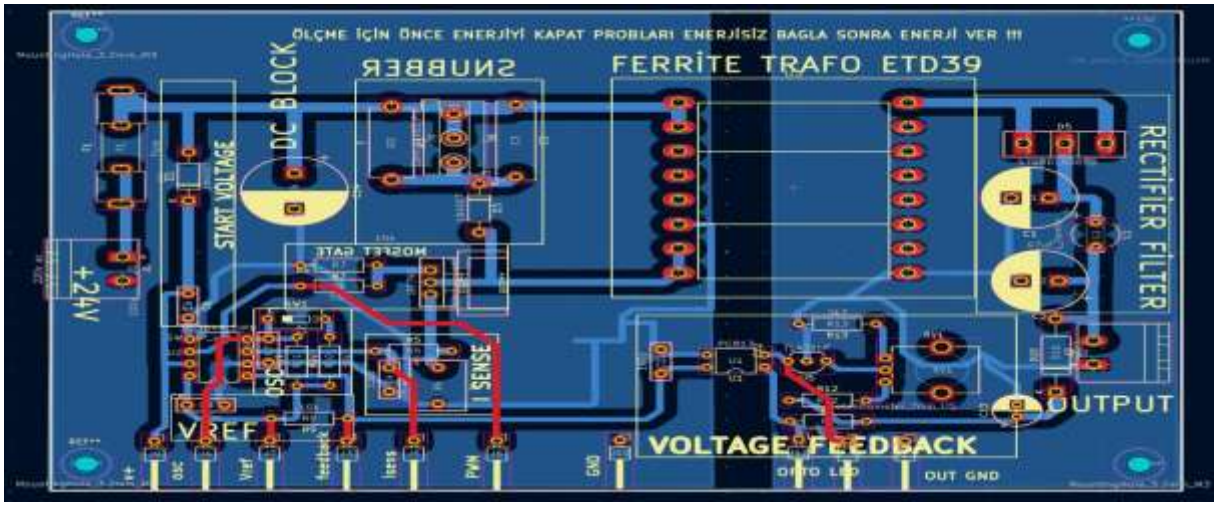
Şekil 2. L1 ve L2 Akım Değerleri Grafiği

Devrede kullanmış olduğumuz potansiyometre ve TL431 yardımı ile görev döngüsü ayarı kolay bir şekilde yapılabilmektedir. (Şekil 3)



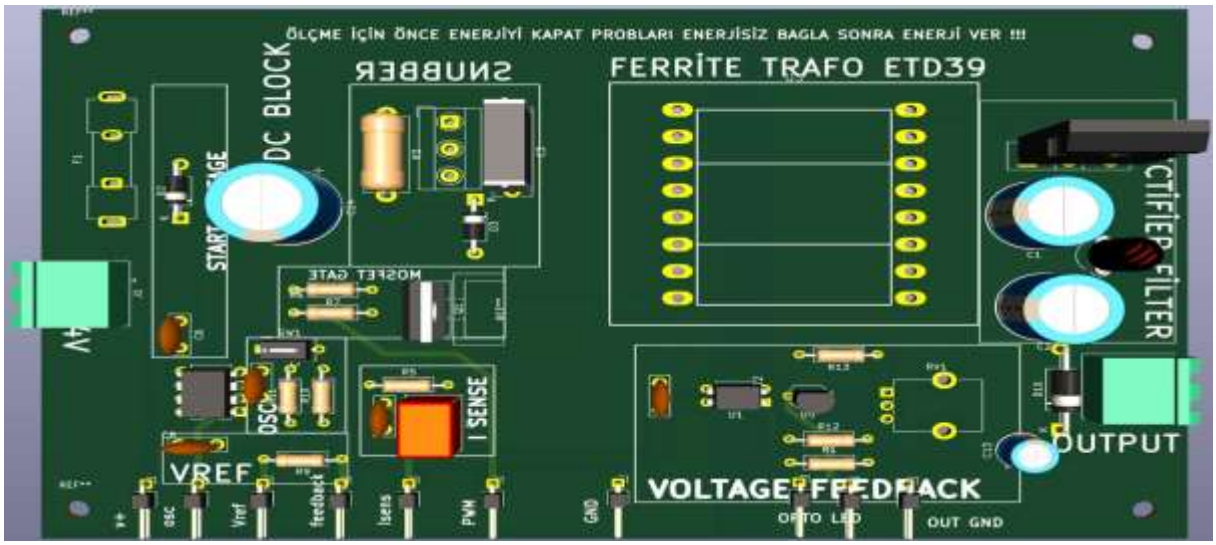
Şekil 3. KiCad Şematik Tasarımı Flyback

İlk enerji verdiğimiz zaman UC3843 PWM entegremiz PULSE üretimine başlar. Bu PWM Mosfetin gate ucundan tetiklenir. Mosfet PWM ile trafo üzerinde enerji indüklenir. Bu indüklenen enerji nüve üzerinden GAP alanı (İki nüve arasındaki boşluk) üzerinden karşı tarafa indüklenir. Bu şekilde çıkış voltajı üretilir. KiCad Pcb tasarımı flyback yapılmıştır. (Şekil 4)



Şekil 4. KiCad PCB Tasarımı

TL431(Voltaj referans entegresi) ile 2.5 voltta tutmaya çalışılır. PC817 optokuplör ile galvanik izolasyon yapılır. Optokuplörün, transistörün TL431 ile seviyesine göre aç kapa yapar bu da UC3843 entegresinin komparatörünü açıp kapatır. Dolayısıyla UC3843' ün PWM duty' sini ayarlar. Flyback devremizin üç boyutlu tasarımı yapılmıştır. (Şekil 5)

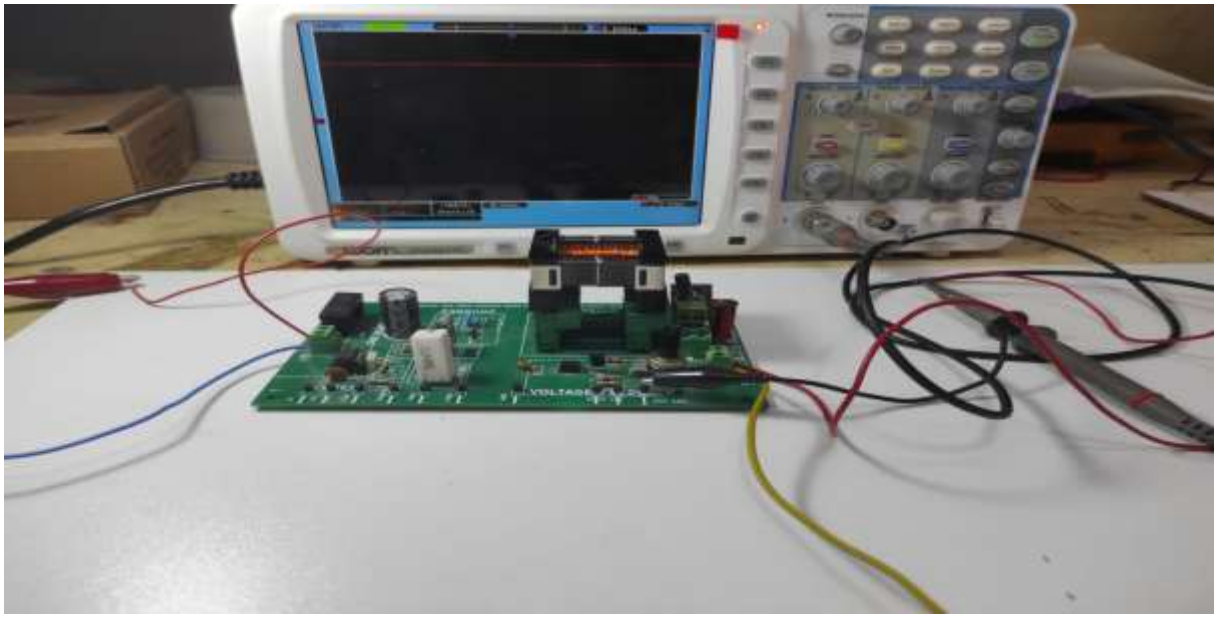


Şekil 5. Flyback KiCad Programı ile Yapılan Pcb Üç Boyutlu Tasarımı

Sonuç ve Öneriler

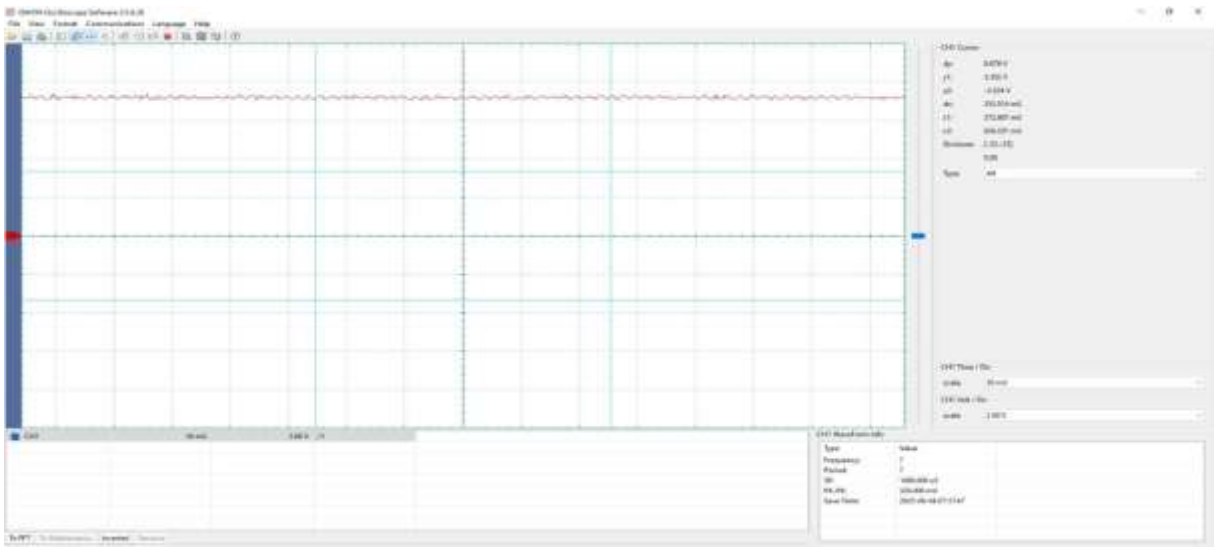
Bu çalışma öğrencilerin farklı kondansatör ve trafo değerlerinin çıkış gerilimi, pulse ve ısens akım değerinin ölçülebildiği bir güç kaynağı devresi eğitim kiti olarak hazırlanmıştır.

Primer sargısı 2,857 mh sekonder sargısı 4.153 mh olan trafomuz ile yapılan flyback devremizin çıkış gerilimi ölçümü aşağıdaki gibidir. (Şekil 6)



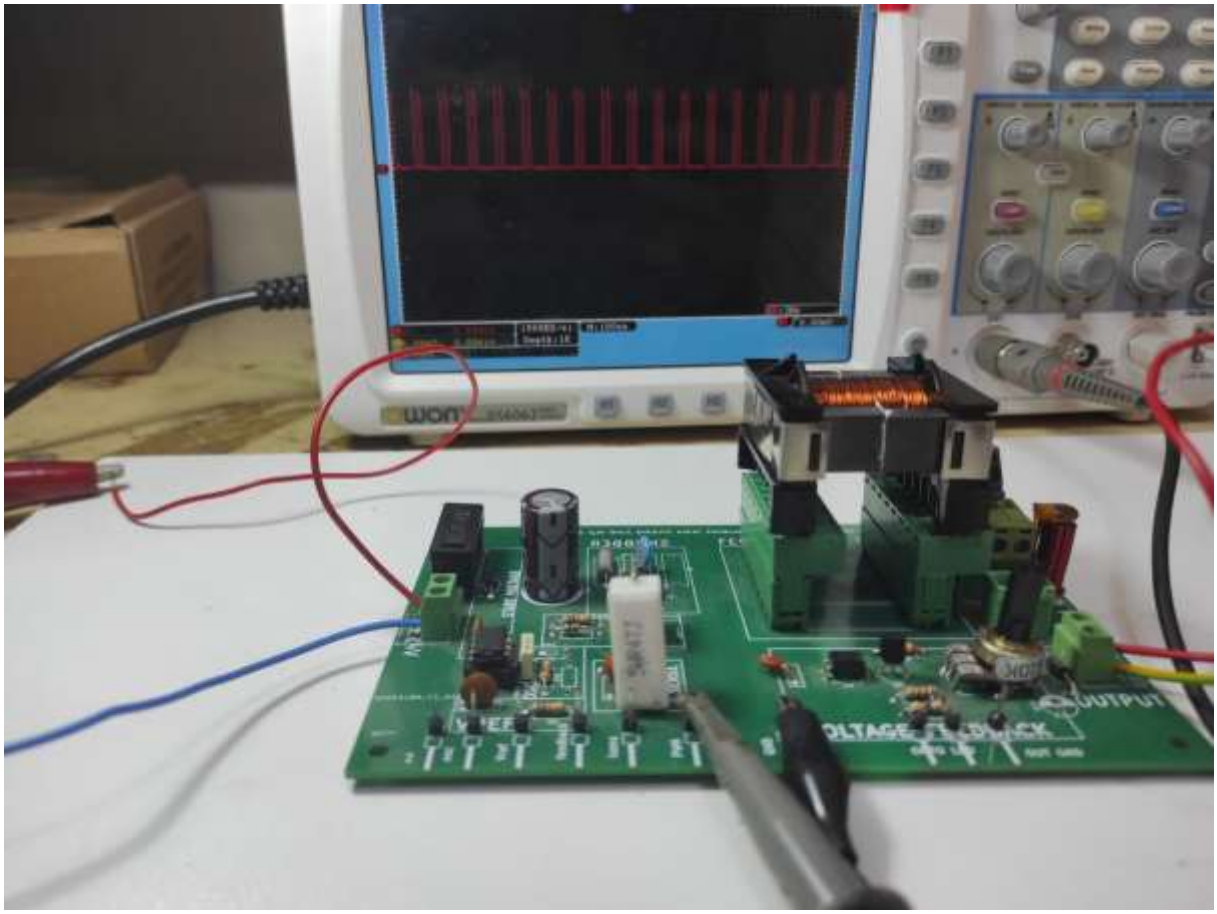
Şekil 6 Flyback Devresi Çıkış Gerilimi Ölçümü 1

Verilen devrenin çıkış gerilim değeri dalga grafiği aşağıda osiloskop ekranında verilmiştir. (Şekil 7)



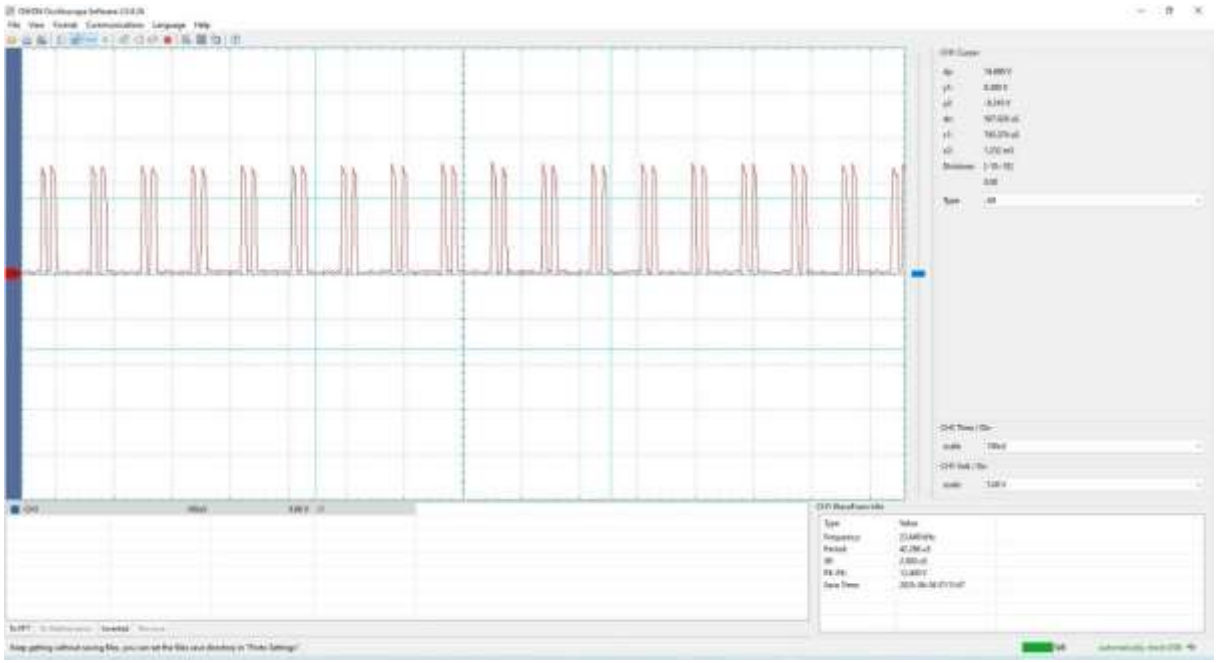
Şekil 7 Çıkış Gerilim Dalga Grafiği Osiloskop Görüntüsü 1

Tasarımı gerçekleştirilen flyback devremizin pwm ölçümü aşağıdaki gibidir. (Şekil 8)



Şekil 8 Flyback Devresinin Pwm Ölçümü

Pwm ölçümünün akabinde osiloskop dalga grafiği aşağıdaki gibi elde edilmiştir. (Şekil 9)



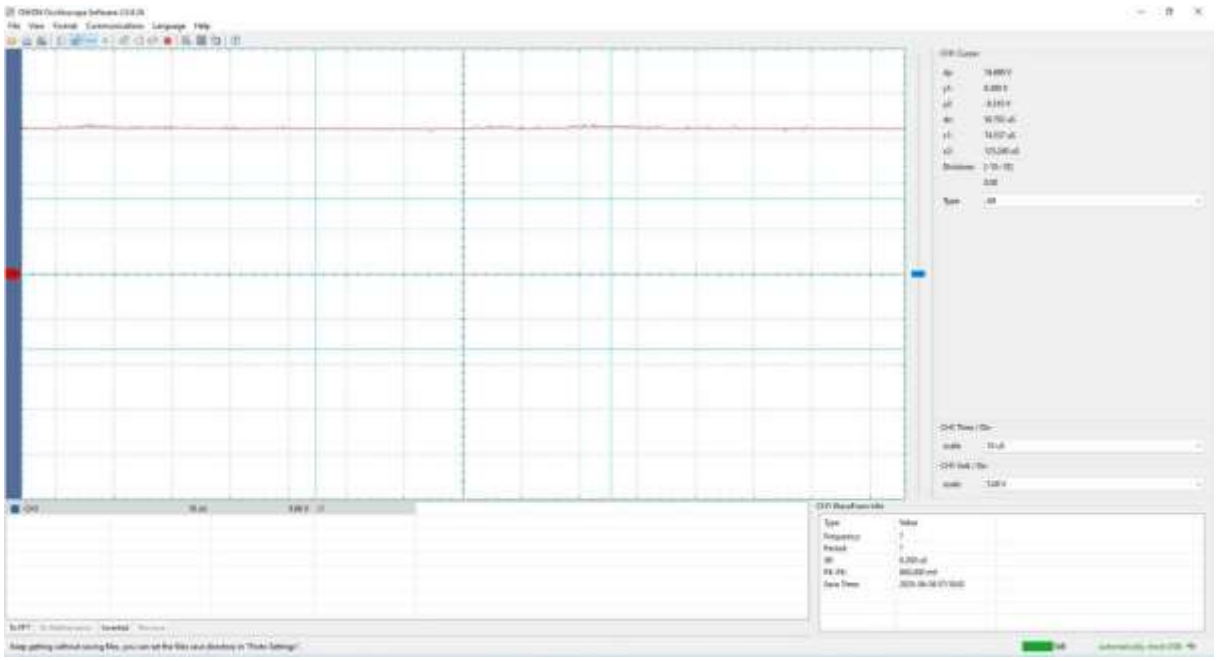
Şekil 9 Pwm Dalga Grafiği Flyback Devremiz 1

Primer sargısı 2.168 mh sekonder sargısı 9.441 mh olan trafomuz ile gerçekleştirdiğimiz flyback devresinin çıkış gerilimi ölçümü aşağıda verilmiştir. (Şekil 10)



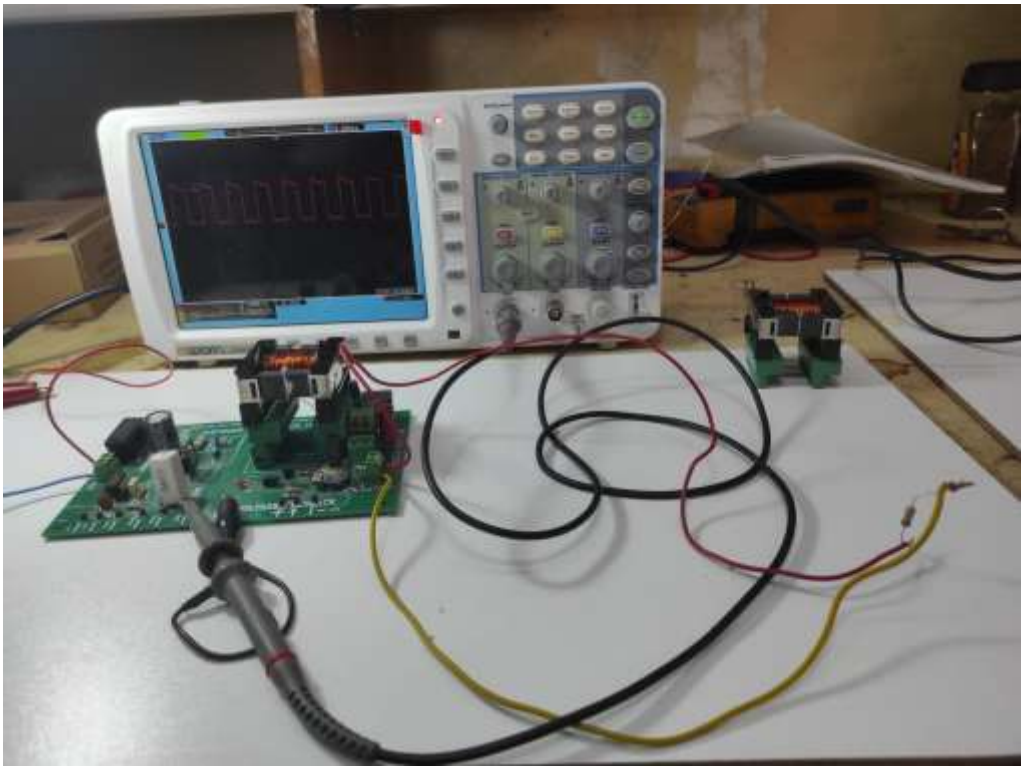
Şekil 10 Flyback Devresi Çıkış Gerilimi Ölçümü 2

Verilen devrenin osiloskop ekranındaki çıkış gerilim dalga grafiği aşağıda verilmiştir. (Şekil 11)



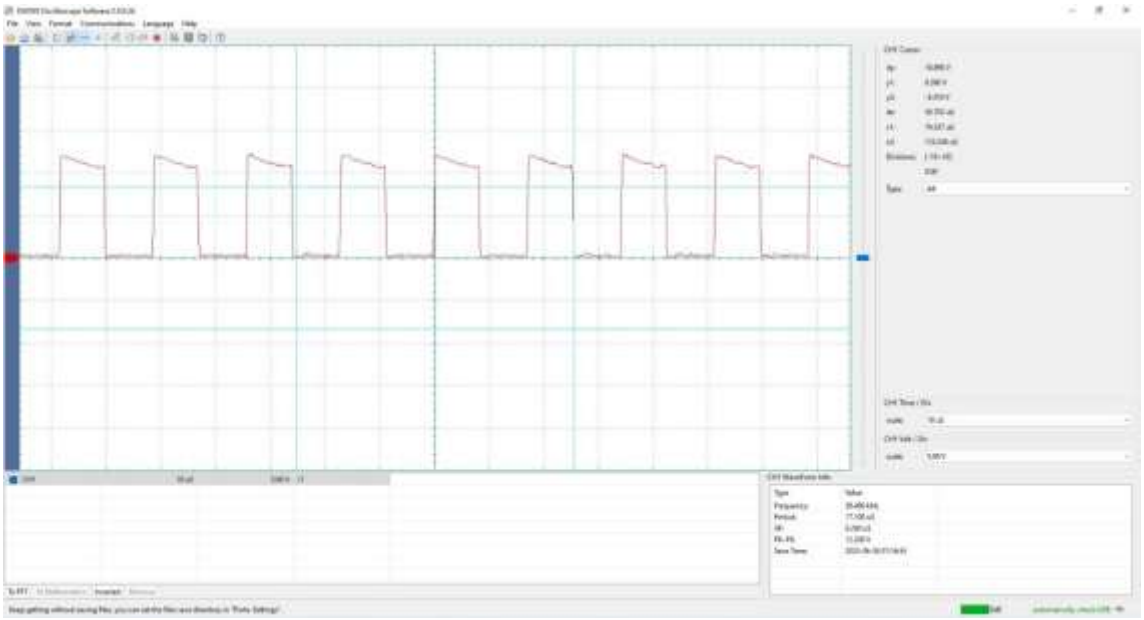
Şekil 11 Çıkış Gerilim Dalga Grafiği Osiloskop Görüntüsü 2

Devremizin pwm ölçümü aşağıda verilmiştir. (Şekil 12)



Şekil 12 Flyback Devremiz Pwm Ölçümü 2

Ölçümü gerçekleştirilen devremizin osiloskop ekranındaki dalga grafiği aşağıda verilmiştir. (Şekil 13)



Şekil 13 Pwm Dalga Grafiğimiz Flyback Devremiz 2

Teşekkür ve Bilgi Notu

Çalışmalarımızda Ahmet Serdar YILMAZ hocamıza çok teşekkür ediyoruz.

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INVESTIGATING TEACHING MICROECONOMICS WITH MATHEMATICAL COMPETENCE: THE CASE OF POLITICAL SCIENCE AND PUBLIC ADMINISTRATION DEPARTMENT

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ABSTRACT

In this study, the relationship between the mathematical competencies and the success of the first- and second-year students taking the Microeconomics course in the Department of Political Science and Public Administration at Adıyaman University, Faculty of Economics and Administrative Sciences, in the fall semester of 2023-2024 was examined. The main purpose of the research is to determine the reasons for failure in the microeconomics course and to offer solutions to reduce these failures. In the study, in which the exploratory sequential design from mixed-methods research was adopted, quantitative data based on the distribution of achievement grades in two consecutive semesters of face-to-face education have been analyzed first. In the following process, qualitative data have been collected through interview forms. The findings have revealed an increase in the number of high-achieving students and a decrease in the number of low-achieving students in the second semester. This development has been associated with the mathematical thinking supportive activities implemented in the course. The analysis has revealed that inadequate study habits, lack of repetition of learned information, and negative attitudes towards mathematics were the determinants of students' reasons for failure. In addition, a significant number of students rated their interest and ability levels in mathematical subjects as average or below. As a result, it is recommended that mathematical concepts should be made more visible in microeconomics teaching, opportunities for repetition should be increased, and attractive methods should be used in course presentations.

Keywords: Microeconomics Education; Mathematical competencies; Academic Achievement.

Introduction

In the last 50 years, the role of mathematics in economics and its role in economic thought has become more visible, forcing students studying in the Department of Political Science and Public Administration to associate mathematics more closely with their undergraduate courses. This compulsion emerged after the Second World War, when mathematics became more present in economics and students taking economics courses at university began to object to the increase of mathematical topics in economics teaching; students studying in the Department of Political Science and Public Administration began to object to more mathematical topics in economics education (Dogruel, 2012). This opposition raises many questions that need to be answered.

The relationship of Microeconomics (Samuelson & Nordhaus, 1948), which deals with the analysis of the behavior of individual elements in an economy, such as the determination of the price of a single product, the behavior of a single consumer or commercial firm with mathematics (Bilgin, 2006) has brought up the need to clarify the question of how mathematical competence in the paper affects the views and achievements in the Microeconomics course.

In the literature, it has been observed that the number of studies examining the relationship between Mathematics and Microeconomics is not sufficient, and there is a limited number of studies on mathematical topics in Microeconomics teaching. Therefore, in order to contribute to the literature, the mathematical topics in Microeconomics.

Materials and Methods

Exploratory sequential design, which is in the mixed methods category, was used in this study. Mixed methods are defined as using both quantitative and qualitative research questions together (Johnson & Onwuegbuzie, 2004). The exploratory sequential design method has a two-stage structure in which quantitative data are first collected and analyzed and then qualitative data are collected and analyzed. While collecting and analyzing statistical data related to the Microeconomics course constitutes the first stage, collecting and analyzing qualitative data through student interview forms constitutes the second stage. The “Student Interview Form” was developed and applied by the researcher by taking expert opinion in the field of measurement and evaluation in order to determine the opinions of the students about the process. The purpose of choosing this method is that it allows the use of qualitative data to explain quantitative data in more detail. The exploratory sequential design method can collect more data than the data provided by qualitative and quantitative data alone. In addition, it can reduce the limitations of using qualitative and quantitative data alone (Creswell & Plano Clarck, 2011).

In this study, firstly, the statistical results, which are quantitative data about the success results of the Microeconomics course in the 2023-2024 and 2024-2025 academic years, are given and these data are analyzed in detail based on expert opinions. The grade distributions in these years were then compared. In order to explain the quantitative data, the data in the interview forms were also included.

Findings and Discussion

The letter grade distribution for the Microeconomics course for the 2023-2024 academic year is graphized below:

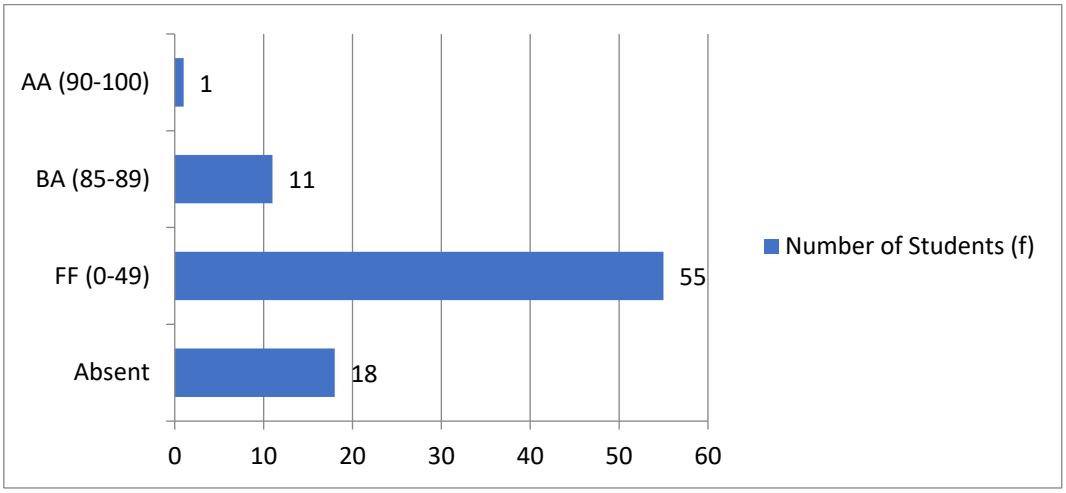


Figure 1. Letter grade distribution for microeconomics course for 2023-2024 academic year

According to expert opinions, 51.40% of the group of 107 students failed this course. In addition, the rate of students who did not attend the course was also high (32.71%). Figure 1 shows that 61.79% of the students who attended the course failed. This high failure rate suggests that students have difficulty in learning the target behaviors (Gocmen, 2004). In interviews with unsuccessful students, it was frequently mentioned that mathematics subjects were the main reason for this difficulty. Especially among undergraduate students studying in different departments, it has been observed that there are significant difficulties in reading and analyzing graphs in courses (Bayazit, 2011). One of the main reasons for the negative reaction of students to the use of mathematical expressions in economics courses is that mathematics seems to be an end in itself, rather than just a tool (Dogruel, 2012).

In addition to these, the university located in Adıyaman province, which is among the provinces most affected by the Kahramanmaras-based earthquake on February 6, 2023, which is referred to in the literature as the “Disaster of the Century” and its aftershocks, may have experienced a decrease in students' achievement scores as a result of problems arising from the psychosocial effects of students, distance education after the earthquake, inability to participate in the course with remote access due to problems arising from the lack of internet infrastructure, etc. (Sert et al., 2024).

The letter grade distribution for the Microeconomics course for the 2024-2025 academic year is graphed as follows:

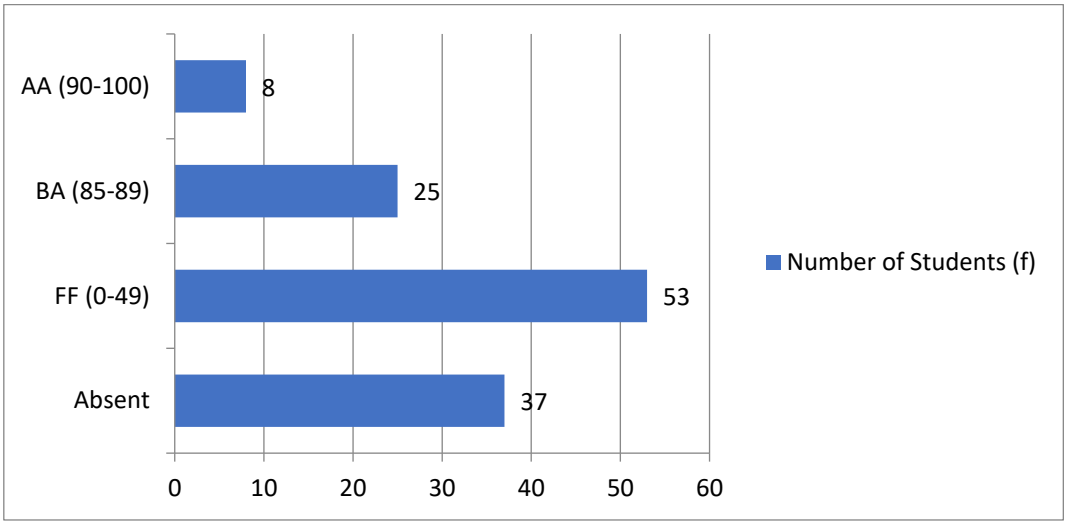


Figure 2. Letter grade distribution for microeconomics course for 2024-2025 academic year

As can be seen in Figure 2, in the studies conducted with the same class two years later, the number of absent students in the group of 108 students was 37. It was determined that 34.3% of the class failed the course due to absenteeism. It is seen that 49,07% of the students who attended the course failed the Microeconomics course with a letter grade of FF. This decrease in FF letter grading compared to the previous year can be associated with the organization of different activities that will gain mathematical thinking away from the logic of exams and questions carried out in the process. As found in the literature, it has been said that leading economists have been engaged in mathematics education, that as a result of these efforts, advances in mathematics have become a necessity for economics to follow, and as a result, mathematical conceptualization has found a serious place in economics (Bilgin, 2006). As a result, students who experience mathematics anxiety see mathematics, which is a tool, as a goal and focus on mathematics rather than the economics content in their lessons and express that they have difficulty and cannot do it.

Such a high rate of failure in the course was evaluated by the students under several headings (n=5) in the interview forms in which 37 students participated. In the second question of the fourth heading of the interview question, student opinions were taken about the success results of the course and the claim of failure among the students who attended the course, and the opinions of the group of students (n=30) who attended the course at 80% and above, whose answer was reached in the first question of the first heading, were as follows:

Table 1. Answers to the Second Question of Title Four and Number of Students

Number of Students (f)	Students' Answers
15	Inadequate study habits
14	Prejudice against the mathematics course
6	Lack of mathematics foundation
4	Failure to attract enough attention in the lesson

As seen in Table 1, 40.5% of the students who participated in the interview stated that inadequate study habits caused the mentioned failure despite attending the course, while 37.8% stated that the prejudice against the mathematics course caused this failure. The opinions in Table 1, which are similar to the opinions of the students who had difficulty in learning in the letter grade distribution for the Microeconomics course for the 2023-2024 academic year, were again asked with another question in the interview to clarify whether this difficulty was due to lack of experience by questioning the students' experience with the mathematical topics in the Microeconomics course. Of the answers given on a 5-point Likert scale ranging from very good to not at all, 72.97% (n=27) indicated that their experience with mathematical topics in Microeconomics course was moderate or above. This answer, given by students whose participation in the course was 80% and above, indicates that the students think that their experience with mathematical topics in the Microeconomics course was moderate or above, and that it cannot be concluded that this difficulty was experienced due to lack of experience. This rate is in line with the previously mentioned finding more space for mathematical topics in undergraduate economics courses.

In the next question, students were asked about their views on mathematical subjects and the level of their interests and abilities. Their answers are tabulated below:

Table 2. Answers to the Second Question of the Second Title and Number of Students

Number of Students (f)	Students' Answers
8	Average interest and ability
6	Below interest
5	Below ability
2	High interest and ability

When the levels of students' interests and abilities are examined together with their views on mathematical subjects, it is seen that students support the view that they have difficulty in mathematical subjects (n=7), that they do not consider their interests and abilities sufficient

(n=11), that students with high interest and ability (n=2) can encounter mathematics in all areas of life and that they can forget the subjects when the information learned is not repeated (n=3). It is seen that the students who have the last opinion (that subjects can be forgotten when the information learned is not repeated) are considered not only by the students with high interest and ability but also by other students. This view reveals that the concept of "repetition", which takes place in the form of references to the previous topic emphasized in the Microeconomics textbooks and the repetition of the opinions given a few pages ago, finds a response in the opinions of the students (Yildirim et al., 2018).

Other data obtained for the Microeconomics course for the 2024-2025 academic year are as follows: The class average for the final and make-up exams was 35.36, the standard deviation for both exams was 14.42, the number of students who did not take the final exam was 53, the number of students who did not take the make-up exam was 29, and the class level was evaluated as "Poor".

The letter grade distribution comparison graph for the Microeconomics course for the 2023-2024 and 2024-2025 academic years is as follows:

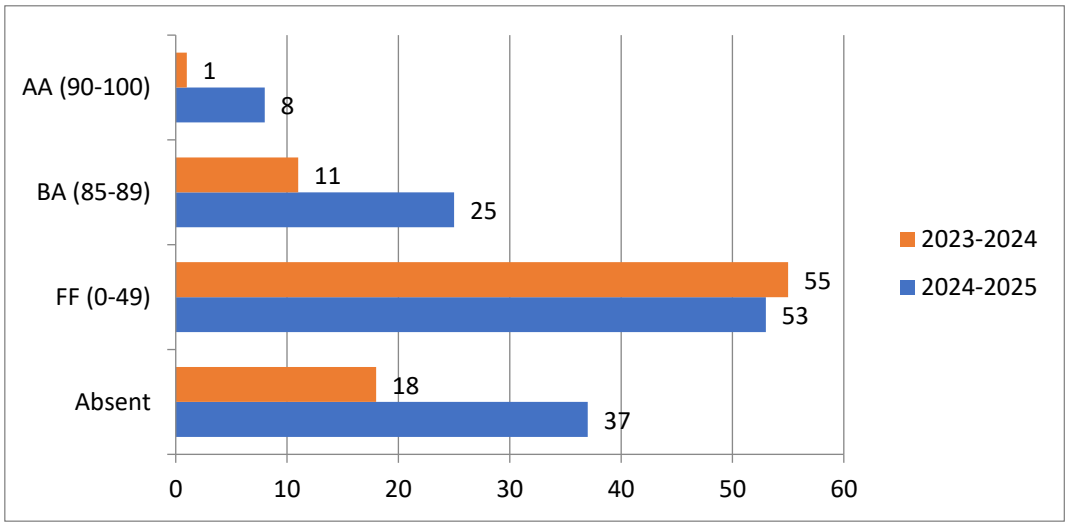


Figure 3. Microeconomics course letter grade distribution comparing 2023-2024 and 2024-2025 academic years

The results obtained in Figure 3 show that the number of students who failed the course due to the attendance requirement, which is at the top of the graph, has more than doubled compared to two years ago. The number of students who failed the course with a letter grade of FF decreased by 2. On the other hand, it is understood from the graph that the number of students who passed the course with the letter grade AA increased from 1 to 8, and the number of students who passed the course with the letter grade BA increased from 11 to 25.

Compared to the previous year, students with AA and BA letter grades constituted 11.21% of the class, while this percentage increased by 30.5% in the following year. This increase can be analyzed with many different variables. The emphasis on the association of mathematics with economics during the first seminar may be one of these variables. The relationship between economics and mathematics can be possible by explaining the use of mathematical concepts in economics that facilitate the understanding and interpretation of economics (Bilgin, 2006). In this way, the students' perspective towards the course may have changed and positively affected their learning.

Although the opinions of the students who failed the Microeconomics course were not obtained separately, one of the students who participated in the interview form stated that the reason for absenteeism was that the course overlapped with another course (n=1). Suggestions to prevent absenteeism were stated in the interview forms as follows:

- "*If attendance were not compulsory, friends who do not understand would not have to come and it is more efficient to continue with friends who are highly motivated.*" S1 continued his views as follows "*Let's aim to reconcile everyone with mathematics. Our priority should be to break the prejudice and bring friends to mathematics. I think that economics is a blended logical course, not within the scope of mathematics, and that we should first break down the prejudice of friends with a caring attitude. We should increase the morale and motivation of curious and volunteer friends, and we should not force those who cannot do the subjects. The first problem arose when we first met math. But we can overcome this with support. Seminars and activities that we can support will break the prejudice.*"
- S10 "*Actually, we need to understand that everything ends in oneself and how we motivate ourselves. Most of the students start with the prejudiced words 'I can't do it, I don't know', thinking that they will not succeed in the lessons. I think we should emphasize this issue more sensitively. I think we can overcome this problem by giving seminars and explaining the lessons in a more entertaining way.*"
- S18 "*Using computer programs, doing group work, debating with the teacher frequently, breaking the subjects into small pieces and comprehending them better, there may be days to practice.*"

As discussed above, it is thought that students' prejudices, lack of morale and motivation, extracurricular activities and seminars, teaching the lessons in an entertaining way, using computer programs, group work, dividing the topics into subheadings, debates with academics and practice will have positive results for students. It is thought that these answers, which are not written only to prevent absenteeism, are the things to be done in order to better understand mathematical subjects and to be successful.

Conclusion and Recommendations

In this paper, the reflection of the place of mathematics subjects in economics education, which has continued from the 19th century to the present day, on students was examined both on the basis of achievement points and with the help of interview forms. The data including the letter grade distributions for the Microeconomics course for the 2023-2024 and 2024-2025 academic years were analyzed separately and comparatively. As a result of the quantitative data supported by the qualitative data in the interview forms, it was seen that students attributed their failures to problems such as prejudice, insufficient understanding of the course, lack of repetition, lack of past experience in mathematics, etc. As a result of the practices carried out after the first year, there was an increase in the number of students with AA and BA letter grades in the second year and a decrease in the number of students with FF letter grades.

As a result of the research, suggestions for instructors teaching Microeconomics courses are as follows:

- In line with students' opinions, lessons can be made more efficient and mathematical concepts can be made more visible.

- Students can be encouraged to develop positive attitudes by using interesting methods in lesson presentations.
- At the beginning of the lesson, the topics of the previous lessons can be summarized and the topics and concepts of the previous lessons can be repeated.
- In order to understand mathematical concepts, definitions of these concepts can be included.
- Students can be encouraged to participate in different types of discussions such as debates, seminars, etc. and express their ideas.
- Students can be encouraged to take part in informative events such as symposiums and congresses where experts in the field take part.

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ABSTRACT

Future literacy is defined as the knowledge, skills and understanding that individuals and societies need in order to comprehend, anticipate, and engage with the future. Within the framework of the social foundations of education, pre-service teachers have the role of educating individuals for future societies; within the framework of the individual foundations of education, they are responsible for preparing individuals for the future. This underscores the importance of identifying their cognitive structures related to future literacy. The lack of studies in the literature that aim to examine pre-service teachers' cognitive structures regarding the terminology of future literacy highlights the originality and significance of this study. The absence of studies in the literature that aim to examine pre-service teachers' cognitive structures regarding the terminology of future literacy reveals the original value of this research. Based on this, the present study aimed to investigate the cognitive structures of pre-service teachers related to concepts associated with future literacy. The study group of the study, which is a qualitative study designed with a descriptive scanning model, consists of 143 senior teacher candidates studying in different departments of a state university. The data were collected using the word association test for the concepts of "futurism, dystopia, utopia, robotics, vision, transhumanism, science fiction, foresight, innovation, sustainability, artificial intelligence, digitalization, colonization of Mars, augmented reality, metaverse, future, virtual reality" determined within the scope of the relevant literature. The data of the study were analyzed with the content analysis technique. As a result of the data analysis, it was determined that the teacher candidates associated more concepts in their cognitive structures towards the concept of "future" compared to other concepts. In addition, it was determined that the teacher candidates established insufficient relationships between the concepts related to future literacy and could not establish any relationships between many concepts.

Keywords: future, future literacy, pre-service teacher

ÖĞRETMEN ADAYLARININ GELECEK OKURYAZARLIĞI İLE İLİŞKİLİ KAVRAMLARA YÖNELİK BİLİŞSEL YAPILARININ İNCELENMESİ

ÖZET

Günümüz toplumları çevre kirliliği, küresel ısınma, afetler, çok kültürlülük, adalet, yapay zekâ, yeni teknolojiler gibi her türlü karmaşık sorun ve zorluklarla uğraşmaktadır. Bu zorlukların gelecekte krize dönüşmemesi için geleceği düşünerek senaryolar üretmek ve bugünden eylem planları yapmak giderek önem kazanmaktadır. Bu durum günümüzde gelecek okuryazarlığı becerisine sahip olmanın gerekliliğini ortaya koymaktadır. Gelecek okuryazarlığı; bireylerin ve toplumların geleceği anlamak, öngörmek ve etkileşimde bulunmak için gerekli bilgi, beceri ve anlayışa sahip olması olarak tanımlamaktadır. Öğretmen adaylarının eğitimin toplumsal temeli kapsamında gelecek toplumlara bireyler yetiştirme, eğitimin bireysel temeli kapsamında ise bireyi de geleceğe hazırlama rolü, gelecek okuryazarlığı ile ilgili bilişsel yapılarının tespitinin önemini ortaya koymaktadır. Alanyazında öğretmen adaylarının gelecek okuryazarlığıyla ilgili terminolojiye yönelik bilişsel yapılarını incelemeyi amaçlayan çalışmalara rastlanmamış olması bu çalışmanın özgün değerini ortaya koymaktadır. Buradan yola çıkarak araştırma öğretmen adaylarının gelecek okuryazarlığıyla ilişkili kavramlara yönelik bilişsel yapılarını incelemeyi amaçlamıştır. Nitel bir çalışma olup betimsel tarama modeliyle desenlenen araştırmanın çalışma grubu, bir devlet üniversitesinin farklı bölümlerde öğrenim gören 143 son sınıf öğretmen adayından oluşmaktadır. Veriler ilgili literatür kapsamında belirlenen "fütürizm, distopya, ütopya, robotik, vizyon, transhümanizm, bilim kurgu, öngörü, inovasyon, sürdürülebilirlik, yapay zeka, dijitalleşme, Marsın kolonileşmesi, artırılmış gerçeklik, metaverse, gelecek, sanal gerçeklik" kavramları kelime ilişkilendirme testi kullanılarak toplanmıştır. Çalışmanın verileri içerik analizi tekniği ile analiz edilmiştir. Veri analizi sonucunda öğretmen adaylarının "gelecek" kavramına yönelik bilişsel yapılarında diğer kavramlara kıyasla daha fazla kavramı ilişkilendirdikleri tespit edilmiştir. Ayrıca öğretmen adaylarının gelecek okuryazarlığıyla ilgili kavramlar arasında yetersiz düzeyde ilişki kurdukları, birçok kavram arasında ise hiç ilişki kuramadıkları belirlenmiştir.

Anahtar Kelimeler: gelecek, gelecek okuryazarlığı, öğretmen adayları

GİRİŞ

İnsanoğlu doğası gereği geleceği düşünmekte, geleceğe yönelik merak duygusunu beslemekte, bu doğrultuda çeşitli planlar yapmakta, hedefler belirlemekte, hedeflerine hazırlanmaktadır (Uymaz ve Cebeci, 2024; Acar, 2019). Jason vd. (1989) tarafından yapılan çalışmada, insanların geleceği düşünmek için geçmişe kıyasla neredeyse iki kat daha fazla zaman harcadıklarını tahmin ettiklerini göstermektedir. Klinger ve Cox (1987) ise rastgele zamanlarda örneklemek için kullandıkları bir çağrı cihazı aracılığıyla insanların günlük aktiviteleri sırasında düşüncelerinin nasıl şekillendiğini inceledikleri çalışmalarında, örneklenen düşüncelerin %12'sinin gelecekle ilgili olduğunu gözlemlemişlerdir. Daha yakın zamanda D'Argembeau ve arkadaşlarının (2011) 19-28 yaş aralığındaki katılımcıların uyandıkları andan uykuya daldıkları ana kadar yani tipik bir gün boyunca geleceğe yönelik düşüncelerini (gelecekte belirli bir zamanda gerçekleşebilecek olaylara yönelik düşünceler veya gelecekte herhangi bir olaya yönelik olmayan genel düşünceler) kaydetmelerinin istendiği çalışmalarında, katılımcıların ortalama olarak bir günde 59 geleceğe yönelik düşünce deneyimlediklerini, bu da yaklaşık olarak her 16 dakikada bir geleceğe yönelik düşünce deneyimlemeye karşılık geldiğini tespit etmişlerdir. Bu bulgular geleceğe yönelik düşüncenin insanın zihninde önemli bir yer tuttuğunu göstermektedir.

Günümüz dünya vatandaşları çevre kirliliği, küresel ısınma, afetler, çok kültürlülük, adalet, yapay zekâ, yeni teknolojiler gibi her türlü karmaşık zorun ve zorluklarla uğraşmaktadır. Bu zorlukların gelecekte krize dönüşmemesi için geleceği düşünmek, gelecek ile ilgili senaryolar üreterek bugünden eylem planları yapmak giderek önem kazanmaktadır (Bol vd, 2023). Bu durum günümüzde gelecek okuryazarlığı becerisine sahip olmanın gerekliliğini ortaya koymaktadır. İlk olarak Wendy Schutz'un doktora tezinde kullandığı "gelecek akıcılığı" (futures fluency) ifadesi ile şekillenmeye başlayan gelecek okuryazarlığı kavramı (Schultz, 1995) daha sonra Riel Miller'in bir dizi makalesine konu olmuştur (Miller, 2006, 2007, 2011, 2015, 2018, 2022). Miller (2022) gelecek okuryazarlığını; bireylerin ve toplumların geleceği anlamak, öngörmek ve etkileşimde bulunmak için gerekli bilgi, beceri ve anlayışa sahip olması olarak tanımlamaktadır. Ayrıca bu kavramın; geleceği okumak, farklı senaryoları değerlendirmek ve gelecekteki olasılıkları keşfetmek için önemli bir yetenek olduğunu belirtmektedir. En yalın şekli ile "geleceği şimdiki zamanda aktif olarak kullanma becerisi" olarak ifade edilmektedir (Poli, 2021).

Gelecek okuryazarlığı bize öngörü gücü vererek adeta bir kâhin gibi geleceğe yönelik tahmin üretme becerisi kazandırmak yerine, olası geleceği keşfetmeye ve ona hazırlanmaya, tercih edilen gelecekleri belirlemeye ve eylem araştırması gibi öğrenme sürecinde gelişimi amaçlayan neyin gerekli olduğunu tespit etmeye yardım etmektedir (Kokshagina, 2021).

Eğitim sistemimizin geleceğini şekillendirecek olan temel öğelerden biri bugünün öğretmen adaylarıdır. Öğretmen adaylarının eğitimin toplumsal temeli kapsamında gelecek toplumlara bireyler yetiştirme, eğitimin bireysel temeli kapsamında ise bireyi de geleceğe hazırlama rolü, gelecek okuryazarlığı ile ilgili bilişsel yapılarının tespitinin önemini ortaya koymaktadır. Gelecek okuryazarlığı henüz gelişiminin erken aşamalarında olsa da öğretmen adaylarının gelecek okuryazarlığı becerisi ile ilgili zihinlerindeki yapılanmanın, bu beceri kapsamındaki terminolojiye olan hâkimiyetlerinin tespiti, gelecek konusuna olan bakış açıları, motivasyon düzeyleri, geleceği düşünüp düşünmedikleri ve bu düşüncelerini gelecek okuryazarlığı becerisi doğrultusunda temellendirebilme kapsamında ipuçları sunacaktır. Bu ipuçları gelecek odaklı eğitim politikalarının düzenlenmesinde, ders içeriklerinin oluşturulmasında ve geleceğin öğretmenleri olan öğretmen adaylarının bu kapsamdaki temel ihtiyaçlarının belirlenmesinde veri kaynağı olarak kullanılabileceği öngörülmektedir. Alanyazında öğretmen adaylarının gelecek okuryazarlığı ile ilgili terminolojiye yönelik bilişsel yapılarını incelemeyi amaçlayan

çalışmalara rastlanmamış olması bu çalışmanın özgün değerini ortaya koymaktadır. Bu araştırmadan elde edilen sonuçların gelecek okuryazarlığı konusunda literatüre katkı sağlaması beklenilmektedir.

Bu araştırmanın amacı öğretmen adaylarının gelecek okuryazarlığı ile ilişkili kavramlara yönelik bilişsel yapılarını incelemektir. Bu amaca ulaşmak adına şu alt sorulara yanıtlar aranmaktadır:

1. Öğretmen adaylarının gelecek okuryazarlığı ile ilgili terminolojiye yönelik bilişsel yapıları nasıldır?
2. Öğretmen adayları gelecek okuryazarlığı terminolojisi kapsamında yer alan kavramlar arasındaki bağlantıyı nasıl kurmaktadırlar?

YÖNTEM

Araştırmanın modeli

Öğretmen adaylarının gelecek okuryazarlığı kavramı ile ilişkilendirilen fütürizm, distopya, robotik, vizyon, transhümanizm, ütopya, bilim kurgu, öngörü, inovasyon, sürdürülebilirlik, yapay zeka, dijitalleşme, marsın kolonileşmesi, artırılmış gerçeklik, metaverse, gelecek, sanal gerçeklik kavramlarına yönelik yeterli düzeyde kavramsal yapıya ve kavramlar arası ilişkiye sahip olup olmadıklarının incelenmesi amacıyla yürütülen bu araştırma nitel bir çalışma olup betimsel tarama modeli kullanılarak tasarlanmıştır.

Araştırmanın çalışma grubu

Araştırmanın çalışma grubunu, 2024-2025 eğitim-öğretim yılı bahar döneminde bir devlet üniversitesi eğitim fakültesinin farklı bölümlerinde son sınıflarında öğrenim gören, kolay ulaşılabilir durum örneklemesi yöntemiyle araştırmanın veri toplama sürecine dâhil edilen 143 öğretmen adayı oluşturmaktadır. Öğretmen adaylarının 99'u kadın, 44'ü erkektir. Öğretmen adaylarının bölümlere dağılımları şöyledir: 22'si Sınıf Eğitimi ABD, 27'si İlköğretim Matematik Eğitimi ABD, 15'i Fen Bilgisi Eğitimi ABD, 21'i Sosyal Bilgiler Eğitimi ABD, 16'sı Türkçe Eğitimi ABD, 23'ü Psikolojik Danışma ve Rehberlik ABD ve 19'u Okulöncesi Eğitimi ABD.

Veri toplama aracı

Araştırmanın verileri kelime ilişkilendirme testi (KİT) kullanılarak toplanmıştır. Bu araştırmada kullanılacak KİT'in hazırlık aşamasında gelecek okuryazarlığı kavramına yönelik literatür taraması yapılmış (Altun, 2020; D'argembeau, 2011; Uymaz, 2023; Uymaz & Cebeci, 2024; Yavuzer vd, 2005) ve Altun (2020) tarafından gelecek okuryazarlığı terminoloji kapsamında yer alan fütürizm, distopya, robotik, vizyon, transhümanizm, ütopya, bilim kurgu, öngörü, inovasyon, sürdürülebilirlik, yapay zeka, dijitalleşme, marsın kolonileşmesi, artırılmış gerçeklik, metaverse, gelecek, sanal gerçeklik kavramları bu araştırmada anahtar kavramlar olarak belirlenmiştir.

Veri toplama aracı hazırlanırken anahtar kavramların ve bu kavramlara yönelik üretilen cevapların birbirlerine etkileme, tekrarlanma olasılığı göz önünde bulundurulmuş, bu amaçla her sayfaya ayrı bir anahtar kavram ve istenilen yanıt sayısı (beş yanıt) gelecek şekilde düzenleme yapılmıştır. Öğretmen adaylarına her bir anahtar kavram için 40 saniye süre verilmiş, bu süre içerisinde adayların ilgili anahtar kavrama yönelik akıllarına gelen ilk beş kelimeyi/kavramı alt alta sıralamaları istenmiştir.

Verilerin analizi

Bu aşamada öncelikle her anahtar kelime için öğretmen adayları tarafından ilişkilendirilen kelime/kavramlara yönelik frekans tablosu hazırlanmıştır. Ardından anahtar kavramlar arasındaki ilişkinin tespit edilmesi için kavram ağı oluşturulmuştur. Kavram ağının oluşturulmasında frekans tablosundan yararlanılmış, her bir anahtar kavramın diğer anahtar kavramlar içerisindeki tekrar sayısı dört aralığa (aralık değeri 10) göre şematize edilmiştir. Kavram ağlarının oluşumu sürecinde belirlenen aralık değerleri ve bu değerlerin göstergesi olarak tercih edilen okların rengi şu şekildedir:

2-11 arası: sarı; 12-21 arası: yeşil; 22-31 arası: mavi; 32 ve üstü: kırmızı

Veri analizinin geçerlik ve güvenirliği

Araştırma sonuçlarının güvenirliğini sağlamak için iki araştırmacı tarafından ayrı ayrı kodlama ve kategorileştirme süreci yapılmış, ortaya çıkan kod ve kategoriler karşılaştırılarak veri analizine son şekli verilmiştir. Bu kapsamda Miles & Huberman (1994) tarafından geliştirilen [görüş birliği / (görüş birliği+ görüş ayrılığı)*100] formül kullanılmış, kodlayıcılar arası ortalama güvenirliğin %89 olduğu tespit edilmiştir. Araştırma sonuçlarının geçerliğini arttırmak için veri analizi sürecinde kavramsal kategorilerin oluşturulması aşamasında hangi kaynaklardan yararlanıldığı araştırmanın tartışma bölümünde bu araştırmadan elde edilen sonuçlarla ilişkilendirilerek açıklanmıştır (Daymon & Holloway, 2003).

BULGULAR

Aşağıdaki tablolarda araştırmaya katılan öğretmen adaylarının anahtar kavramlara yönelik cevap kelime/kavram sayıları kategorileştirilerek frekans değerleri ile birlikte sunulmaktadır.

Tablo 1. Transhümanizm kavramına yönelik KİT analizi sonuçları

Kategoriler	**f**	**Kavramlar (f)**
Kimlik	53	İnsan (28), İnsanın değişimi (13), İnsan ötesi (10), Yetenek (2)
Toplumsal cinsiyet	50	Cinsiyet (12), Gey (8), Trans birey (8), Cinsiyetsizlik (7), Eşcinsellik (6), LGBT (5), Erkek (2), Kadın (2)
Toplum	38	Farklılık (12), Eşitlik (7), Saygı (6), Sevgi (4), Toplum (4), Çeşitlilik (3), Özgürlük (2)
Bakış açısı	24	Düşünce (5), Hümanist (4), Felsefe (4), Fikir (4), Anlayış (3), Hümanist olmayan (2), Akım (2), Din (2)
Değişim	23	Değişim (11), Dönüşüm (4), Geçiş (4), Gelecek (2), Yok etmek (2)
Değer	15	Hoşgörü (5), İyimserlik (5), Ahlaksız (3), Günah (2)

Tablo 1 incelendiğinde katılımcı öğretmen adaylarının "transhümanizm" kavramı ile ilişkilendirdiği kavramların 6 kategoride toplandığı, bu kategoriler kapsamında birbirinden farklı 37 kavram ilişkilendirmesi yapıldığı tespit edilmiştir. Ayrıca adayların transhümanizm kavramını daha çok "kimlik" ve "toplumsal cinsiyet" kategorisindeki kavramlarla ilişkilendirdikleri dikkati çekmiştir. Bu anahtar kavramın özellikle cinsiyete dair kavramlarla ilişkilendirilmesinin adayların transhümanizm kavramına yönelik kavram yanılgılarına sahip olduklarını göstermektedir.

Tablo 2. Ütopya kavramına yönelik KİT analizi sonuçları

Kategoriler	**f**	**Kavramlar (f)**
Hayali	141	Hayali (58), Selena (25), Hayali dünya (20), Hades (8), Hayal gücü (6), Hayal ürünü (6), Hayalperest (4), Yüce Honos (4), Alışılmamış (3), Pandora (3), Hayal dışı (2), Hayali hedef (2)
Gelecek	60	Distopya (10), Gelecek (9), Farklı (7), Ulaşılamayan (6), İmkansızlık (6), Uzak (3), Hayat (3), Cennet (2), Çarpıcı (2), Hedef (2)
Gerçeklik	54	Gerçek dışı (16), Olağandışı (11), Gerçek üstü (8), Var olmayan (6), Düşsel (5), Kurgu (3), Sıradışı (3), Gerçekleşmesi mümkün (2), Sihirli (2)
Yaşam alanı	39	Dünya (14), Evren (7), Gezegen (7), Yaşam Alanı (7), Uzay (4)
Bakış açısı	37	Düşünce (9), Bilinçaltı (4), Fikir (4), Felsefe (4), Bilimsel (3), Duygu (3), Bilgi (2), Bilinmeyen (2), İyi düşünce (2), Kıvılcım (2), Yaratıcılık (2)
İdeal olan	22	Mükemmellik (6), Olumlu dünya (4), Thomas More (3), Olması istenen (3), Platon (2), İdeal (2), Refah Yaşam (2)
Toplum	14	Devlet (5), Güç (3), Düzen (2), İktidar (2), Ülke (2)
Değer	8	İyilik (3), İstek (3), Umut (2)

Tablo 2 "ütopya" anahtar kavramına yönelik ifade edilen ilişkili kavramların 8 kategoride toplandığını, çoğunlukla "hayali" kategorisi ve "hayali" kavramı kapsamında ilişkilendirme yapıldığını göstermektedir. Ayrıca adayların ütopya kavramıyla birbirinden farklı 62 kavramı ilişkilendirdikleri tespit edilmiştir.

Tablo 3. Metaverse kavramına yönelik KİT analizi sonuçları

Kategoriler	**f**	**Kavramlar (f)**
Yapay Zeka	34	Sanal ortam (13), Yapay dünya (8), Yapay zeka (7), Kripto para (4), Web 3 (2)
Bilim	27	Evren (8), Uzay bilimi (6), Bilinç (4), Metafizik (4), Gerçeklik (3), Fizik (2)
Gelecek	23	Gelecek (7), Hayali (6), Gerçek Dışı (4), 3 Boyut (4), Bilinmeyen (2)
Medya	19	İnternet (7), Facebook (5), Elon Musk (3), Zükenberg (2), Film (2)
Bilişim	15	Bilgisayar (4), Yazılım (4), Program (3), Kodlama (2), Uygulama (2)
Teknoloji	15	Teknoloji (10), Yenilik (3), Dijitalleşme (2)

Tablo 3 öğretmen adaylarının "metaverse" anahtar kavramına yönelik ifade edilen ilişkili kavramların 6 kategoride toplandığını, çoğunlukla ise "yapay zekâ" kategorisi kapsamında ilişkilendirme yapıldığını göstermektedir. Ayrıca analiz sonucunda adayların metaverse kavramını 29 farklı kavramla ilişkilendirdikleri de tespit edilmiştir.

Tablo 4. Dijitalleşme kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Teknoloji	170	Teknoloji (76), Telefon (29), Bilgisayar (23), Tablet (10), Robot (9), TV (7), Akıllı araç gereç (5), Elektrik elektronik (4), Makineleşme (3), Yazılım (2), Kodlama (2), Uçan araba (2)
İletişim	45	Sosyal medya (20), Asosyallik (9), İletişim (5), Instagram (4), Sosyalleşme (4), Yalnızlık (3)
Avantaj	43	Kolaylık (22), Hızlı (8), Modernleşme (4), Evrensellik (3), Uyum (2), Sürdürülebilirlik (2), Aktif (2), Hayat (2)
İnternet	39	İnternet (21), Ekran (9), Online işlemler (3), Çağ (3), Ekonomi (3), Erişim (2)
Riskler	33	Uzak (18), Teknoloji bağımlılığı (5), Bağımlılık (4), Soyutlaşma (4), Tek düzen (2)
Ortam	33	Dijital ortam (14), Sanal ortam (8), Dünya (4), Global dünya (3), Oyun (2), Gerçek (2)
Yenilik	27	Yenilik (12), Gelişim (8), İlerleme (3), Güncel (2), Yeni dünya (2)
Bilgi	16	Bilim (6), Bilgi (4), Bilgi alışverişi (2), Eğitim (2), Dijital okuryazarlık (2)

Tablo 4 incelendiğinde katılımcı öğretmen adaylarının "dijitalleşme" anahtar kavramıyla ilişkilendirdikleri kavramların 8 kategori kapsamında ve en fazla "teknoloji" kategorisinde toplandığı tespit edilmiştir. Ayrıca adayların bu kategoriler kapsamında birbirinden farklı 53 kavramla ilişkilendirme yaptıkları belirlenmiştir.

Tablo 5. İnovasyon kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Yenilik	98	Yenilik (53), Gelişme (25), İlericilik (6), Çağdaşlaşma (4), İcat (2), Buluş (2), Reform (2), Güzellik (2), Güncel (2)
Teknoloji	46	Teknoloji (30), Robotik (5), Kodlama (4), Yapay Zeka (3), Bilgisayar (2), Java (2)
Dönüşüm	44	Değişim (13), Yenileme (8), Farklılaştırma (5), İyileştirme (5), Dönüşüm (3), Restore etmek (3), Uyum (3), Dönüştürme (2), Değiştirme (2)
Bilim	20	Bilim (7), Bilimsel (3), Bilişim (3), Eğitim (3), Kimya (2), Disiplin (2)
Gelecek	20	Gelecek (9), Düzen (7), Sürdürülebilirlik (2), Hayat (2)
Yaratıcılık	12	Yaratıcılık (6), Hayali (4), Kurgu (2)
Üretim	11	Üretim (3), Ürün (2), Yön (2), Yapı (2), Şirket (2)

Tablo 5'e göre öğretmen adaylarının "inovasyon" anahtar kavramıyla ilişkilendirdikleri kavramların 7 kategoriye ayrıldığı ve bu ilişkinin en fazla "yenilik" kategorisinde olduğu tespit

edilmiştir. Ayrıca adayların anahtar kavramla ilgili birbirinden farklı 42 kavram ürettikleri; bu kavramlar arasında sıklıkla tekrarlanan kavramın "yenilik" olduğu belirlenmiştir.

Tablo 6. Gelecek kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Duygu	133	Kaygı (60), Umut (16), Stres (13), Korku (11), Endişe (7), Umutsuzluk (6), Mutsuzluk (4), Üzüntü (4), Mutlu (3), Yorgunluk (3), Depresyon (3), Sevgi (3), Sıkıntı (3), Tükenmişlik (3), Boşluk (2), Heyecan (2)
Gelecek	89	Zaman (19), İleriye dönük (17), Bilinmezlik (13), Belirsizlik (12), Plan (4), Fütürizm (4), Ümit (4), Yarın (4), Düşündürücü (3), Uzak (3), Parlak (2), Değişim (2), Vizyon (2), Yaşlılık (2)
Anlam Arayışı	85	Hayal (16), Hayat (15), Yaşam (9), Beklenti (8), Hedef (6), Yaşanmamış (3), Başarı (3), Geçmiş (3), Şu an (3), Ahiret (2), Amaç (2), Gerçek dışı (2), Kendini gerçekleştirme (2), Özgürlük (2), Yalan (2)
Toplum	70	Para (9), Meslek (9), Evlilik (6), İş Bulma (5), Parasızlık (5), Ekonomi (5), İşsizlik (4), Nesil (4), Öğretmenlik (4), Düzen (4), Aile (3), Dünya sorunları (3), Su (2), Maddiyat (2)
Teknoloji	45	Yapay zeka (9), Teknoloji (7), Yenilik (7), Bilim (5), Robot (5), Sanal ortam (3), Uzay (3), Bilim kurgu (2), Yeni çağ (2)
Distopya	25	Karanlık (5), Karamsarlık (3), Kötümser (3), Yok olmak (3), Zorluk (3), Distopya (2), Ölüm (2), Savaş (2), Kıtlık (2)

Tablo 6 incelendiğinde "gelecek" anahtar kavramıyla ilgili öğretmen adaylarının 6 kategoride toplanan, birbirinden farklı 77 kavramı ilişkilendirdikleri görülmektedir. Adayların en fazla "duygu" temasına yönelik kavramlar ürettikleri ve sıklıkla "kaygı" duygusunu tekrarladıkları dikkati çekmiştir.

Tablo 7. Fütürizm kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Sanat	98	Akım (28), Sanat (22), Modernizm (15), Edebiyat (9), Resim (8), Nazım Hikmet (7), İtalya (7), Minyatür (2)
Zaman	78	Gelecek (65), Geçmiş (6), Zaman (4), Şimdi (3)
Toplum	43	Toplum (21), İş (5), Para (4), Yaşam (4), Hareket (4), Sanayi (3), Eşitlik (2)
Bilim	37	Makine (13), Bilim (8), Teknoloji (7), Bilim kurgu (6), Hız (3)
Bakış Açısı	23	Felsefe (7), Hayal (6), Düşünce (5), Gerçekçilik (5)
Duygu	9	Kaygı (7), Umut (2)

Fütürizm kavramına yönelik üretilen KİT' in yer aldığı Tablo 7 incelendiğinde öğretmen adaylarının yanıtlarının 6 kategoride ve sıklıkla "sanat" başlığı altında toplandığı

görülmektedir. Adaylar bu anahtar kavramı birbirinden farklı 32 kavramla ilişkilendirirken, sıklıkla tekrarlanan kavramın ise "akım" olduğu tespit edilmiştir.

Tablo 8. Robotik kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Robotik	162	Yapay zekâ (53), Robot (47), Zekâ (10), İnsanüstü (10), Mekanik (8), Makine (7), Mühendislik (7), Teknolojik tasarım (6), Makineleşme (5), Köle (2)
Teknoloji	157	Teknoloji (49), Kodlama (43), Yazılım (17), Bilgisayar (11), Kod (6), Programlama (5), İnternet (5), Dijital (5), Sistematik (3), Araç (2), Sistem (2), Sanal dünya (2)
Modernite	40	Gelecek (23), Yeni dünya (5), Sanayi (2), Modernleşme (2), Çağ (2), Dünya (2), Teknoloji Devri (2), Düzen (2)
İnovasyon	38	Kolaylık (12), Gelişim (10), Teknolojik (5), İlerleme (3), Kurgu (2), İnovasyon (2), Elon Musk (2), Hazırcılık (2)
Elektronik	11	Elektrik (6), Hız (3), Elektronik (2)
Bilim	29	Bilim (25), Matematik (2), Bilimsel (2)

Tablo 8 incelendiğinde öğretmen adaylarının "robotik" anahtar kavramını 6 kategori altında birbirinden farklı 44 kavramla ilişkilendirdikleri görülmektedir. Ayrıca adayların "robotik" kavramını sıklıkla "yapay zekâ" kavramı ile ilişkilendirdikleri de ortaya çıkan bir diğer bulgu olmuştur.

Tablo 9. Distopya kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Kurgu	131	Hayal (37), Ütopya (35), Hayal dünyası (21), Gerçek dışı (13), Olağanüstü (7), Gelecek (7), Kurgu (4), Rüya (3), Cesur Yeni Dünya (2), 1984 (2)
Yaşam alanı	33	Dünya (14), Gerçek dünya (6), Ülke (6), Evren (4), Düzen (3)
Kaos	25	Olumsuz (8), Baskı (7), Kötü (4), Kötü dünya (2), Belirsizlik (2), Kaos (2)
Felsefe	23	Düşünce (6), Fikir (4), Felsefe (4), Yaşam (2), İnsan (2), Bilim (2), Yaratıcılık (3)

Tablo 9'a göre "distopya" anahtar kavramıyla ilişkilendirilen kavramların 4 kategori altında birleştiği ve en fazla "kurgu" kategorisi kapsamında toplandığı tespit edilmiştir. Adayların bu anahtar kavramla ilgili birbirinden farklı 28 kavram ürettikleri ve sıklıkla "hayal" kelimesini tekrarladıkları belirlenmiştir.

Tablo 10. Vizyon kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Gelişim	102	Hedef (67), Gelişmişlik (10), İstek (6), Çaba (5), Başarı (5), Görev (3), İlke (2), Yükselmek (2), Disiplin (2)
Bakış açısı	59	Düşünce (18), Görüş (23), İleri görüşlü (5), Algı (3), Düşünce tarzı (4), Parlak fikir (2), Hayal (4)
Yenilik	19	Yenilik (6), Yaratıcılık (5), Farklılık (3), Değişim (2), Yeni (2), Değişiklik (1)
Kişisel özellikler	13	Özgünlük (3), Özveri (2), Sezgi (2), Cesaret (2), Hoşgörü (1), Değer (2), Önemi (1)
İş yaşamı	6	Çalışma (2), Kariyer (2), Plan (2)

Tablo 10 incelendiğinde "vizyon" anahtar kavramıyla ilişkilendirilen kavramların 5 kategori kapsamında ve en fazla "gelişim" başlığı altında birleştiği görülmektedir. Ayrıca bu anahtar kavramın birbirinden farklı 32 kavramla ilişkilendirildiği ve sıklıkla tekrarlanan kavramın "hedef" olduğu belirlenmiştir.

Tablo 11. Bilim kurgu kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Bilimsellik	81	Bilim (37), Bilimsellik (17), Bilgi (2), Deney (10), Gözlem (2), Laboratuvar (2), Fen (5), Matematik (2), Bilgisayar (2), Araştırma (2)
Medya	79	Film (42), Dergi (7), Kitap (7), Animasyon (5), Sinema (4), Dizi (4), Marvel (4), TV (3), Çizgi film (3),
Teknoloji	61	Teknoloji (38), Yapay zekâ (9), Robot (4), Yapay (3), Sanal (3), Makine (2), Bilgisayar (2)
Hayal Dünyası	51	Hayal (12), Kurgu (12), Hayali (8), Hayal ürünü (7), Hayal gücü (5), Roman (3), Hikâye (2), Hayal dünyası (2)
Gerçeklik Algısı	32	Gerçek (12), Gerçek üstü (5), Gerçekçi kurgu (5), Gerçek dışı (4), Gerçek olmayan (3), Gerçekliğe yakın (3)
Gelecek	30	Gelecek (14), Olası (5), Geleceğe dönüş (4), Geleceğe yönelik (3), Sınırsız (2), Sınırları zorlayan (2)
Uzay	21	Uzay (12), Yıldızlararası (5), Zaman (2), Uzak (2)
Düşünce	20	Yaratıcılık (7), Yenilik (5), Akıllıca (2), Bakış açısı (2), Çağdaş (2), Mantık (2)
İnsan	8	İnsan dışı (2), İnsan ürünü (2), İnsan ötesi (2), Astronot (2)

Tablo 11'e göre "bilim kurgu" anahtar kavramı birbirinden farklı 60 kavramla ilişkilendirmiş ve bu kavramlar 9 kategori etrafında toplanmıştır. Kategoriler arasında ise anahtar kavramın en fazla "bilimsellik" kategorisi kapsamında ilişkilendirildiği görülmüştür. Ayrıca adayların "bilim kurgu" anahtar kavramında "film" kavramını sıklıkla tekrarladıkları tespit edilmiştir.

Tablo 12. Sürdürülebilirlik kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Yenilenebilirlik	99	Devamlılık (61), Yenilenebilir enerji (14), Enerji (11), Güneş enerjisi (5), Elektrik (3), Tükenmeyen (3), Rüzgâr (2)
Zaman	71	İleriye dönük (18), Teknoloji (14), Gelecek (12), Nesil (9), Yarın (5), Çağ (5), Zaman (2)
Tutum	70	Çevrecilik (34), Planlılık (16), Uyum (8), İstikrar (7), Odaklanma (5)
Ekonomi	65	Tasarruf (25), Verimlilik (19), Kullanılabilirlik (11), Kaynak (4), Ekonomi (3), Finans (3)
Doğa	57	Doğa (17), Çevre (15), Süreklilik (14), Ekoloji (3), Küresel ısınma (2), İklim (2), Zamansız (2), Döngüsel (2)
Çevre Dostu Uygulamalar	47	Geri dönüşüm (30), Temizlik (8), Çöp (3), Sıfır atık (2), Çöp kutusu (2), Koruma (2)
Toplum	45	Kalkınma (10), Gelişim (7), Hayat (6), Sağlık (5), Eğitim (5), Yaşam (4), İnsan (4), Toplum (2), İlişki (2)

Sürdürülebilirlik anahtar kavramına yönelik KİT analizlerin yer aldığı Tablo 12 incelendiğinde, ilişkilendirilen kavramların 7 kategori etrafında toplandığı, en fazla ilişkilendirilen kategorinin ise "yenilenebilirlik" olduğu görülmektedir. Adayların birbirinden farklı 48 kavram ürettikleri ve sıklıkla tekrarlanan kavramın ise "devamlılık" olduğu belirlenmiştir.

Tablo 13. Marsın kolonileşmesi kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Bilim	143	Buluş (27), Keşif (23), Teknoloji (21), Bilim (19), Kopya (15), Yenilik (12), Gelişim (6), İlerleyiş (5), Değişim (8), Klon (4), Farklılaşma (3)
Uzay	94	Uzay (26), Yeni dünya (14), Mars (11), Dünya (8), Uzay gemisi (5), Uzaylı (5), Uzayda yaşam (3), Astronomi (6), Evren (6), Dünya dışı (4), Başka gezegen (2), İkinci dünya (2), Astroloji (2)
Toplum	79	Nüfus artışı (18), Zenginlik (17), Göç (15), Yerleşim (6), Dış güçler (3), Para (3), Gruplaşma (2), İnsanlık (8), Topluluk (7)
Doğa	66	Yaşam (23), Su (21), Yeni bir yaşam (6), Oksijen (4), Yaşam arayışı (4), Dünyalaştırma (4), Ekoloji (2), Canlılık (2)
Gelecek	25	Ütopya (9), Gelecek (7), Yeni hayat (4), Yeni bir düzen (3), İleriye dönük (2)
Duygu	22	Arayış (11), Hayal (7), Rüya (2), Umut (2)
Tehdit	4	Savaş (2), Dünyanın sonu (2)

Tablo 13 incelendiğinde "Marsın kolonileşmesi" anahtar kavramıyla ilişkilendirilen kavramların 7 kategori etrafında toplandığı, en fazla ise "bilim" kategorisiyle ilişkilendirildiği görülmektedir. Ayrıca adayların birbirinden farklı 52 kavram ürettikleri ve sıklıkla "buluş" kavramını tekrarladıkları tespit edilmiştir.

Tablo 14. Artırılmış gerçeklik kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Gerçeklik	138	Gerçek (15), Gerçeğe yakın (11), Gerçek üstü (8), Gerçeklerin fazlalığı (5), Gerçekliğin doğruluğu (2), Realizm (9), Doğrulanabilir (2), Güvenirlik (16), İnandırıcılık (5), Kanıt (17), Nesnellik (16), Objektiflik (8), Yalan (13), Kurmaca (11)
Yaratıcılık	55	Yaratıcılık (9), Soyutlaşma (2), Olağan üstü (11), Yeni dünya (6), Yenilik (5), Hayal (11), Gelecek (11)
Teknoloji	49	Teknoloji (16), Dijitalleşme (2), Yapay zekâ (22), Robotlar (2), Bilgisayar (5), Apple (2)
Sanal	46	Sanal (5), Sanal âlem (4), Sanal dünya (9), Sanal gerçeklik (3), Sanal ortam (5), Sanal gözlük (2), VR (2), VR gözlük (3), Simülasyon (7), Hologram (2), Yapay (2), Yapay ortamlar (2)
Görsellik	44	3D (21), 3 boyutluluk (3), 3D gözlük (2), 4D (2), Gözlük (16)
Medya	41	Film (14), Korku evi (7), Animasyon (9), Oyun (11)
Bilim	23	Bilim (6), Araştırma (5), Deney (3), Eğitim (2), Sunum (5), Farkındalık (2)

Tablo 14'e göre "artırılmış gerçeklik" anahtar kavramıyla ilişkilendirilen kavramlar 7 kategori etrafında ve sıklıkla "gerçeklik" kategorisi etrafında toplanmıştır. Ayrıca adaylar birbirinden farklı 54 kelime üretirken en fazla tekrarladıkları kavramın ise "kanıt" olduğu belirlenmiştir.

Tablo 15. Sanal gerçeklik kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Teknoloji	79	Teknoloji (21), Bilgisayar (6), Telefon (3), Ekran (2), Dijital (2), Dijitalleşme (6), Dijital ortam (5), Dijital dünya (4), Dijital yaşam (2), İnternet (13), Yapay zeka (15)
Sanal	66	Artırılmış gerçeklik (13), Sanallaşma (16), Sanal ortam (11), Sanal dünya (7), Simülasyon (5), Yapaylık (5), VR (3), Yapay ortam (3), Metaverse (3),
Medya	41	Sosyal medya (14), Oyun (11), Animasyon (5), Film (3), Sinema (3), Kurgu (2), Medya (3)
Gerçeklik	36	Gerçek dışı (17), Gerçeğe yakın (6), Sahtelik (4), Hayali unsurlar (3), Gerçeklik (2), Kandırma (2), Uydurma (2)
Görsellik	36	3D (15), Gözlük (10), 3 boyutlu (5), 3D gözlük (3), Boyut (3)
Yaratıcılık	25	Hayal (7), Hayal ürünü (3), Farklılık (3), Hayal gücü (2), Hayal dünyası (2), Soyut (2), Sınırsızlık (2), Yaratıcılık (2), Yenilik (2)

Tablo 15 incelendiğinde "sanal gerçeklik" anahtar kavramıyla ilişkilendirilen kavramların 6 kategori etrafında birleştiği ve en fazla ilişkilendirilen kategorinin "teknoloji" olduğu belirlenmiştir. Ayrıca adaylar birbirinden farklı 48 kavram üretirken, sıklıkla "teknoloji" kavramını tekrarladıkları tespit edilmiştir.

Tablo 16. Öngörü kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Vizyoner Düşünce	189	Tahmin etmek (75), İleri görüşlülük (25), Önceden bilmek (20), Gelecek (18), Geleceği görme (7), Tecrübe (7), Atatürk (7), İleriye dönük (6), Varsayım (5), Hayal etmek (4), Olasılık (4), Kestirebilme (3), Plan (3), Ön bilgi (3), Yordama (3), Gerçeklik (2), Karakter (2), Vizyon (2)
Biliş	93	Düşünce (19), Fikir (16), Farkındalık (12), Bilmek (7), Çıkarım (6), Görüş (6), Akıl (4), Zeka (4), Bakış açısı (4), Bilgi (3), Yorum (3), Yetenek (3), Yargılamak (2), Tespit (2), İzlenim (2)
Algılama	73	Sezgi (28), Hissetmek (23), Önyargı (11), Altıncı his (5), Üçüncü göz (2), Görmek (2), Duygu (2)

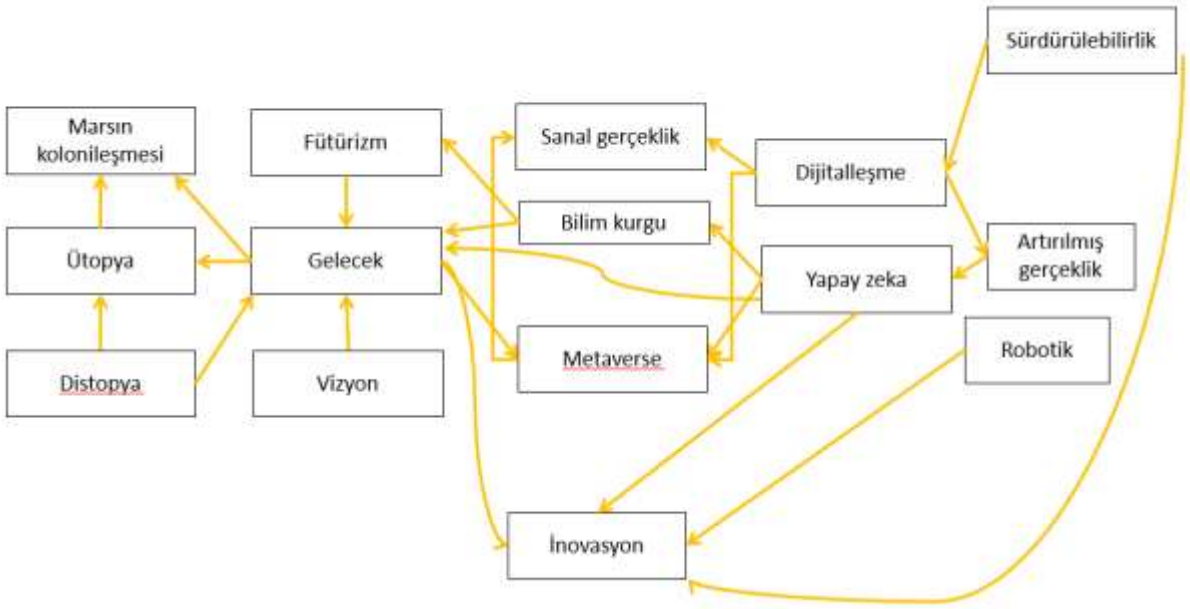
Tablo 16' ya göre "öngörü" anahtar kavramıyla ilişkilendirilen kavramlar 3 kategori altında toplanmıştır. Adayların en fazla "vizyoner düşünce" kategorisiyle ilgili kavramları anahtar kavramla ilişkilendirdikleri görülmüştür. Ayrıca bu anahtar kavramla ilgili birbirinden farklı 40 kavram üretilirken, sıklıkla "tahmin etmek" kavramı tekrarlanmıştır.

Tablo 17. Yapay zekâ kavramına yönelik KİT analizi sonuçları

Kategoriler	f	Kavramlar (f)
Teknoloji	160	Teknoloji (59), Robotik (40), Kodlama (14), Bilgisayar (13), Yazılım (13), Elon Musk (5), Makine (4), Yapay (4), İnternet (3), Artırılmış gerçeklik (3), Mühendislik (2), Matematik (2)
Biliş	74	Bilgi (38), İnsan (7), İnsan üstü (5), Üretken (5), Akıllı (4), Zeka (4), Bilgi veren (3), Düşünce (2), Beyin (2), Cevaplama (2), Yaratıcılık (2)
Araçlar	70	Chat Cpt (52), Grok (4), Google (3), Gemini (3), Dipseek (3), Telefon (3), Canva (2), Uygulama (2)
Kolaylık	67	Kolaylık (42), Hızlı (7), Ödev (6), Sanal Alem (4), Hayali (3), Ulaşılabilirlik (3), Ölüm (2)
Toplumsal Etki	43	Gelecek (21), Yenilik (7), Gelişim (6), Zaman (3), Gerçek (3), Yeni Dünya (3), Erişim (2)
Eğitim-Öğretim	23	Ders Planı (7), Yardımcı (7), Dijital (4), Eğitim (3), Danışma (2)
Riskler	15	Korku (4), Tehlike (4), Tembellik (3), İnovasyon (2), Ürkütücü (2)

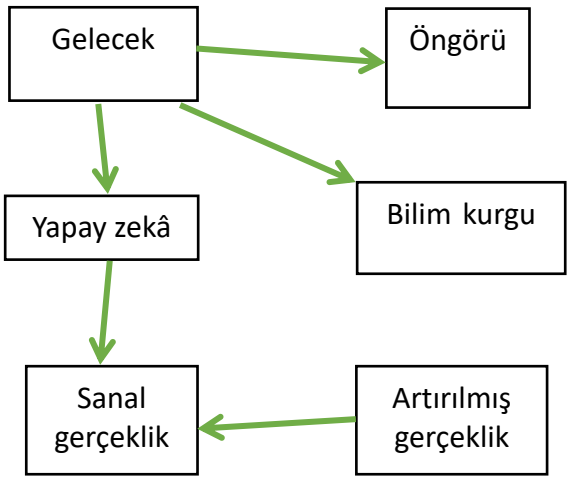
Tablo 17 incelendiğinde öğretmen adaylarının "yapay zekâ" anahtar kavramıyla ilişkilendirdikleri kavramların 7 kategori etrafında toplandığı görülmektedir. Adaylar en fazla "teknoloji" kategorisiyle ilişkili kavramlar ürettikleri, anahtar kavramla ilgili birbirinden farklı 56 kavram ürettiği ve sıklıkla "teknoloji" kavramını tekrarladıkları görülmektedir.

Aşağıda sunulan şekiller katılımcıların anahtar kavramlara yönelik verdikleri cevaplara göre oluşturulmuş kavram ağlarını göstermektedir. Öğretmen adaylarının 2-11 kesme noktasında anahtar kavramlar arasında kurdukları ilişkiyi gösteren kavram ağı Şekil 1'de sunulmuştur.



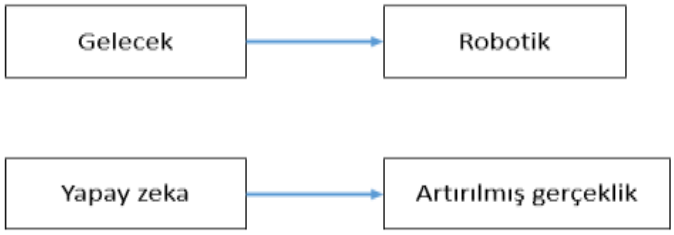
Şekil 1. 2-11 kesme noktasına göre oluşturulan kavram ağı

Şekil 1 incelendiğinde 2-11 kesme noktasına göre öğretmen adaylarının en fazla "gelecek" ve "yapay zekâ" kavramlarıyla diğer kavramlar arasında ilişki kurdukları görülmektedir. Şekilde dikkat çeken bulgulardan bir diğeri ise "vizyon" ve "robotik" kavramlarının diğer kavramlarla az sayıda ilişkilendirildiğidir.



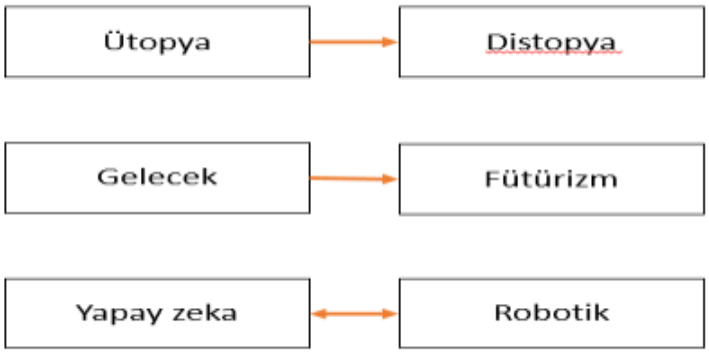
Sekil 2. 12-21 kesme noktasına göre oluşturulan kavram ağı

Şekil 2, katılımcı öğretmen adaylarının bilişsel yapılarında "gelecek" kavramıyla "öngörü", "bilim kurgu", "yapay zekâ" kavramları arasında 12-21 kesme noktasına göre ilişki kurduklarını göstermektedir. Ayrıca adayların "artırılmış gerçeklik" "sanal gerçeklik" ve "yapay zekâ" kavramları arasında da aynı kesme noktaları açısından ilişki kurdukları görülmektedir.



Şekil 3. 22-31 kesme noktasına göre oluşturulan kavram ağı

Şekil 3'e göre öğretmen adaylarının 22-31 kesme noktasına göre ilişkilendirmeleri "gelecek" ve "robotik" kavramı ile "yapay zekâ" ve "artırılmış gerçeklik" kavramları arasındadır.



Şekil 4. 32 ve üstü kesme noktasına göre oluşturulan kavram ağı

Şekil 4 incelendiğinde 32 ve üstü kesme noktasına göre öğretmen adaylarının "ütopya" ile "distopya", "gelecek" ile "fütürizm", "yapay zeka" ile "robotik" arasında ilişki kurduklarını göstermektedir.

Kavram ağlarından elde edilen sonuç öğretmen adaylarının bilişsel yapılarında gelecek okuryazarlığıyla ilişkili kavramlar arasında çok yetersiz düzeyde ilişki kurduklarını, birçoğu ile hiç ilişki kuramadıkları yönündedir.

SONUÇ ve TARTIŞMA

Araştırmadan elde edilen sonuçlara göre katılımcı öğretmen adaylarının transhümanizm anahtar kavramı ile diğer anahtar kavramlar arasında ilişki kurmadıkları, transhümanizm kavramına yönelik bazı öğretmen adaylarının kavram yanılgılarına sahip oldukları tespit edilmiştir. Öğretmen adayları ilgili anahtar kavrama yönelik sıklıkla; cinsiyet, cinsiyetsizlik, eşcinsellik, farklılık, insanın değişimi, gey, trans birey gibi cinsiyet değişikliğini öne çıkaran kavramlar üretmişlerdir. Hâlbuki teknoloji çağının getirilerinden olan ve kökleri rasyonel hümanizme dayanan (Dağ, 2017) transhümanizm, insanın temel özelliklerinin geliştirilmesini amaç edinen bir felsefi akım olup gelecek hakkında bir düşünme yoludur (Demir, 2018). Çoğunlukla iyimser

beklentilerin dile getirildiği bu düşünce biçimi, genetik ve teknolojik müdahalelerle, insan varlığını kısıtlayan zaaf ve arazların ortadan kaldırılabileceğini, sağlıklı ve genç yaşam süresinin uzatılabileceğini varsayar. Hatta insan varlığının kaçınılmaz yönlerinin; ölüm ya da yaşlılık gibi, ortadan kaldırılabileceğini, insan hayatının dijital evrende sonsuza kadar sürebileceğini varsaymaktadır. İnsan zihninin kopyalanması, yapay zekâ uygulamalarının ulaştığı aşama ve bunların gelişim ve yaygınlaşma hızları, transhümanistlerin söylemlerini dayandırdıkları kanıtlardır (Köksal, 2019). Ancak araştırma sonuçları incelendiğinde az sayıda öğretmen adayının transhümanizm kavramına yönelik bilişsel yapılarında; düşünce, felsefe, fikir, anlayış, akım, din gibi kavramların yer aldığı da görülmektedir. Literatürde transhümanizm ile ilişkilendirilen bu kavramları (Aydeniz, 2020; Dağ, 2017, Demir, 2018; Köksal, 2019; Ünal, 2019) üreten öğretmen adaylarının ilgili kavrama yönelik zihinsel yapılarında bazı bilgilerin yer aldığı ancak bu kavram ile gelecek okuryazarlığı terminolojisi kavramında yer alan diğer anahtar kavramlar arasında ilişki kuramadıkları için transhümanizm kavramına yönelik bilişsel yapılarının kapsamdan kopuk olduğu yorumu yapılabilir.

Araştırmanın dikkat çeken bulgularından biri katılımcı öğretmen adaylarından bazılarının gelecek okuryazarlığı kavramının terminolojisinde yer alan" ütopya" kavramına yönelik bilişsel yapılarında 2006 yılında yayın hayatına televizyon dizisi olarak başlayan Selena adlı diziden kelime/kavramların (Selena, Hades, Yüce Honos, Pandora) yer almasıdır. Dizi "genel izleyici" profiline uygun olarak 2006-2009 yılları arasında her hafta ekranlarda çocuk ve gençlere yönelik fantastik kategorisinde bir televizyon projesi olarak yayınlanmıştır (Çiftçi, 2010). Ana teması iyi ve kötü mücadelesi olan filmin "ütopya" gezegeninde geçmesi (Torun,2010) dolayısıyla bazı öğretmen adaylarının bilişsel yapılarında ilgili kavramla ilişkilendirmelerine yol açmıştır. "Ütopya" kelime itibari ile "gerçekleşmesi imkânsız tasarı ve düşünce" olarak Türk Dil Kurumu (Türk Dil Kurumu [TDK], 2022) sözlüğünde yer almaktadır. Köken olarak Yunanca "yok/olmayan" anlamındaki ou, "mükemmel olan" anlamındaki eu ve "yer/toprak/ülke" anlamındaki topos sözcüklerinden türemiştir (Çiftçi, 2010). Yumuşak (2012) ütopyayı "mevcut sistemin aksayan yönlerini eleştiren ve ideal hayat tarzını anlatan hayalî toplumsal projeler" şeklinde tanımlamaktadır. Diziye konu olan ütopya gezegeni de sihirlerin yapıldığı, iyi ve kötünün daima bir yarış içerisinde olduğu mekân olarak tasvir edilmektedir. Dizide ütopya gezegeninde geçen sihir içerikli olayların günlük olaylarla iç içe verilmesi çocukların dizi filmde kendilerinden bir şeyler bulmalarına, kahramanlarını taklit etmelerine ve böylelikle dizinin daha çok akılda kalıcı olmasına imkân vermektedir (Torun, 2010). Kaya ve Tuna 2008 yılında yürüttükleri çalışmalarında Selena dizisinin ortaokul öğrenci tarafından sıklıkla izlenen dizilerden biri olduğunu ve özellikle katılımcı kız öğrenciler tarafından film karakterlerinin rol model olarak alındığını tespit etmişlerdir. Ayrıca bu araştırmada katılımcı öğretmen adaylarının bilişsel yapılarında ütopya anahtar kavramı ile literatürde bu kavram ile ilişkilendirilen; Thomas More, gelecek, hayali, hayal ürünü, hayali dünya, kurgu, gerçeküstü, var olmayan, olağan dışı, devlet, iktidar, ülke vb. kavramlara (Omay, 2009) sahip oldukları da tespit edilmiştir.

Araştırmanın sonucunda katılımcı öğretmen adaylarının gelecek okuryazarlığı terminolojisi kapsamında yer alan; metaverse, yapay zekâ, djitalleşme, inovasyon, robotik, marsın kolonileştirilmesi, artırılmış ve sanal gerçeklik, bilim kurgu kavramlarını bilişsel yapılarında sıklıkla yaratıcılık, hayal, hayal dünyası, hayal ürünü, teknoloji, gerçek üstü, dijitalleşme, robot, teknoloji, bilgisayar kavramları ile ilişkilendirdikleri belirlenmiştir. Sürdürebilirlik kavramına yönelik katılımcıların bilişsel yapılarında sıklıkla geri dönüşüm, devamlılık, çevrecilik kavramlarının yer aldığı, öngörü ve vizyon kavramları ile görüş, düşünce, ileri görüşlülük

kavramlarının sıklıkla ilişkilendirildiği tespit edilmiştir. Katılımcılar fütirizm kavramını ise bilişsel yapılarında sıklıkla gelecek, sanat, akım ve modernizm kavramları ile ilişkilendirmişlerdir. Araştırmadan elde edilen bu bulgular ilgili kavramlara yönelik literatür ile örtüşmektedir (Akboğa, 2021; Bozoğlu ve Ciğerim, 2022; Çınar ve Demir, 2023; İçten ve Bal, 2017; Miller, 2022; Satı, 2023; Şimşek ve Atvur, 2021).

Araştırmada dikkat çeken bulgulardan biri de katılımcı öğretmen adaylarının "gelecek" kavramına yönelik bilişsel yapılarında diğer kavramlara kıyasla daha fazla kelime/kavramı ilişkilendirmeleridir. Gelecek kavramı ile öğretmen adayları birbirinden farklı toplam 77 kavramı ilişkilendirmiş olup, bu kavramlar içerisinde gelecek okuryazarlığı terminolojisi kapsamında yer alan vizyon, fütirizm, distopya, yapay zeka, bilim kurgu kavramlarının (Altun, 2020; Uymaz, 2023) da yer almasıdır. Yalnız bu kavramları gelecek anahtar kavramı ile ilişkilendiren öğretmenlerin sayısı, gelecek kavramını olumsuz duygularla ilişkilendiren öğretmen adaylarının sayısından hayli düşüktür. Gelecek kavramına yönelik katılımcı öğretmen adayları sıklıkla kaygı, stres, korku, umutsuzluk, üzüntü gibi olumsuz duyguları bilişsel yapılarında ilişkilendirmişlerdir. Bu durumun nedeni katılımcı öğretmen adaylarının yükseköğretim süreçlerinin son aşamasında olmuş olmalarından kaynaklı olabilir. Yükseköğretimden mezun olmanın verdiği mutlulukla birlikte öğretmen adaylarının gireceği merkezi sınavlar ve göreve başlamaları konusundaki yaşamış oldukları belirsizlikler nedeniyle gelecek kavramı ile olumsuz duyguları ilişkilendirmeleri beklenir bir sonuçtur. Benzer şekilde Aytar ve Soylu (2019) çalışmalarında üniversite öğrencilerinin geleceğe yönelik en büyük kaygılarının işsizlik olduğunu ifade etmişlerdir. Kara, Akın ve Alp (2020) üniversite öğrencilerinde gelecek kaygısı (umutsuzluk) ile sınav kaygısı arasındaki bir ilişki olduğunu tespit etmişlerdir. İnan vd (2024) çalışmalarında Kamu Personeli Seçme Sınavı'nın öğretmen adayları üzerinde kaygıya yol açtığını saptamışlardır. Araç ve Cihan, (2019) yapmış oldukları çalışmada bu araştırma bulgularını destekler nitelikte üniversite öğrencilerinin gelecek kaygısı yaşadıkları sonucuna ulaşmışlardır. Ancak bu araştırmadan elde edilen sonuçlardan farklı olarak Şanlı-Kula ve Saraç (2016) çalışmalarında üniversite öğrencilerinin orta düzeyde gelecek kaygısına sahip olduklarını ifade etmişlerdir. Araştırmalar arasında ortaya çıkan bu farklılıkların nedenleri, araştırmaların amaçları, kullanılan yöntem ve örneklem grubu farklılıkları olabilir.

Araştırma bulgularından hareketle oluşturulan kavram ağında öğretmen adaylarının sıklıkla gelecek anahtar kavramı ile diğer kavramlar (marsın kolonileştirilmesi, ütopya, distopya, fütürizm, vizyon, bilim kurgu, inovasyon, metaverse, yapay zeka) arasında düşük frekans değerinde ilişki kurdukları tespit edilmiştir. Ayrıca kavramlar arası en yüksek ilişkinin; gelecek ile fütürizm arasında olduğu tespit edilmiştir. Bu bulgular katılımcı öğretmen adaylarının gelecek kavramlarını zihinsel yapılarında merkeze aldıklarını ve diğer kavramları bu ana kavramla ilişkilendirdiklerini göstermektedir. Bu durumun olası nedeni gelecek düşüncesinin konu ağının ve kaynağının genişliği olabilir. Altun (2020) geleceğin teknoloji, bilim kurgu, sanat çalışmalarında sıklıkla ele alınan bir konu olduğunu, fütürizm gibi sanat akımlarının gelecek konusuna kaynaklık edeceğini ifade etmektedir.

Sonuç olarak bu araştırmaya katılan öğretmen adaylarının gelecek okuryazarlığı ile ilgili terminolojiye yönelik bilişsel yapılarının genel olarak yeterli olduğu ancak bazı kavramlara yönelik kavram yanılgılarına sahip oldukları, terminoloji kapsamındaki kavramlarla ilişkili olarak olumlu ve olumsuz kavramları ilişkilendirdikleri, bu kavramlarında sıklıkla birbirleriyle benzerlik taşıdığı tespit edilmiştir. Öğretmen adayları gelecek okuryazarlığı ile ilgili kavramlar

arasındaki bağlantıyı "gelecek" kavramı üzerinden kurdukları, bu kavramı merkeze alarak diğer kavramlarla ilişkilendirdikleri tespit edilmiştir. Araştırmadan elde edilen bulgular doğrultusunda şu öneriler geliştirilmiştir:

1. 21. yüzyıl becerileri arasında yer alan gelecek okuryazarlığına yönelik, 21. yüzyılın bireylerini yetiştirecek ve böylelikle toplumsal yapıyı şekillendirecek olan öğretmen adaylarının bu okuryazarlık becerisi kapsamında temel kavramlara olan hâkimiyetlerinin hizmet öncesinde arttırılmasına yönelik tedbirler alınabilir.
2. Üniversite öğrencilerinin gelecek kaygılarını etkileyen değişkenlerin nicel ve nitel araştırma yöntemleriyle incelendiği çalışmaların sıklığı attırılarak yüksek kaygının azaltılması amacıyla kurumlar arası işbirliği ile (örneğin Aile Ve Sosyal Hizmetler Bakanlığı ve Yüksek Öğretim Kurumları) kaygının azaltılmasına yönelik tedbirler alınabilir.
3. Gelecekte öğretmenlerin ve öğretmen adaylarının bu araştırmada geçen anahtar kavramlara yönelik bilişsel yapılarını etkileyebilecek değişkenlerin (örneğin cinsiyet, yaş, kıdem, ekonomik durum, izledikleri film, okudukları kitap türü vb.) incelendiği çalışmalar yürütülerek gelecek okuryazarlığı terminoloji bilgisine etki eden faktörlerin belirlenmesi sağlanabilir.
4. Benzer araştırma farklı örneklem türleri üzerinde tekrarlanabilir.

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THE IMPACT OF INTERNATIONAL ACCOUNTING STANDARDS (IAS 41) ON AGRICULTURAL FINANCIAL REPORTING

A Systematic Literature Review

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ABSTRACT

The agricultural sector plays a crucial role in many economies worldwide and presents distinct challenges for financial reporting due to the unique nature of biological assets and agricultural produce. International Accounting Standard 41 (IAS 41), introduced by the International Accounting Standards Board (IASB) in 2003, aims to standardize the accounting treatment for agricultural activities, with particular emphasis on the fair value measurement of biological assets. This literature review systematically examines the impact of IAS 41 on agricultural financial reporting by employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to select, screen, and synthesize relevant academic and professional literature published between 2003 and 2024. The findings indicate that IAS 41 has significantly enhanced the transparency, comparability, and relevance of agricultural financial statements. However, challenges such as valuation complexity, market illiquidity, earnings volatility, and implementation barriers especially in developing countries persist. Furthermore, the review explores stakeholder perceptions and country-specific adoption issues, providing insights into ongoing debates surrounding fair value accounting in agriculture. Key research gaps are identified, including the need for more empirical studies focused on emerging economies and small and medium-sized agricultural enterprises. Overall, the study underscores the mixed but transformative influence of IAS 41 on agricultural accounting practices and highlights the necessity for tailored guidance and capacity building to optimize the standard's global benefits.

Keywords: IAS 41, Agricultural Financial Reporting, Biological Assets, Fair Value Accounting, Implementation Challenges, Developing Countries

1. Introduction

The agriculture sector is inherently different from other industries in terms of its economic activities, risk factors, and asset management. It deals with living animals and plants—collectively termed biological assets which undergo continual transformation due to growth, procreation, degeneration, or harvest. These processes, known as biological transformation, introduce significant complexity and uncertainty in financial reporting (Elad & Herbohn, 2011). Agricultural entities must contend with issues such as unpredictability in biological growth rates, the impact of climatic conditions, disease, and fluctuating market prices for both inputs and outputs (Argilés et al., 2011). These unique features demand a specialized accounting framework that reflects the true nature and value of agricultural operations.

To address these challenges, the International Accounting Standards Board (IASB) introduced International Accounting Standard 41 (IAS 41) - Agriculture, which became effective in 2003. IAS 41 was the first standard to require the use of fair value as a basis for measuring biological assets and agricultural produce at the point of harvest, rather than historical cost (IASB, 2001). The standard mandates that biological assets be measured at fair value less estimated costs to sell, with changes in fair value recognized in profit or loss for the period in which they arise. The objective is to provide users of financial statements with more relevant and timely information on the performance and financial position of agricultural businesses.

While IAS 41 enhances transparency and comparability across entities and jurisdictions, it has also generated debate and practical difficulties in implementation. Critics argue that fair value accounting may introduce volatility into financial statements and that reliable market data is often unavailable for certain biological assets, especially in developing countries (Fiechter & Meyer, 2010; Mates et al., 2017). Moreover, the standard's principles-based nature leaves room for judgment and estimation, raising concerns over consistency and reliability in its application (Bozzolan et al., 2011).

In light of these issues, it is crucial to evaluate how IAS 41 has affected financial reporting in the agricultural sector over time. This systematic literature review employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to identify, assess, and synthesize empirical studies, theoretical frameworks, and professional insights related to the adoption, implementation, and consequences of IAS 41. The goal is to provide a comprehensive understanding of the standard’s impact on accounting practices, decision-making, and financial statement users within the agricultural domain.

2. Methodology

2.1 Method

This This study employs a systematic literature review (SLR) approach, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA guidelines provide a structured and transparent method for conducting literature reviews, ensuring that the process is replicable, comprehensive, and methodologically sound (Moher et al., 2009). The aim of adopting this approach is to identify, evaluate, and synthesize relevant academic contributions concerning the integration and impact of International Accounting Standards (IAS 41) on Agricultural Financial Reporting.

To collect a robust set of academic sources, a systematic search was conducted across four major scholarly databases: Scopus, Web of Science, ScienceDirect, and Google Scholar. These databases were selected due to their comprehensive coverage of peer-reviewed journals,

conference proceedings, and scholarly articles in accounting, finance, information systems, and emerging technologies. The search was performed between March and May 2025.

The inclusion criteria were clearly defined to maintain the relevance and quality of the literature selected. The following conditions were applied:

- ✓ Only peer-reviewed journal articles and conference papers were included.
- ✓ The publications had to be written in English.
- ✓ The publication date range was limited to 2003–2024 to ensure a focus on recent developments and applications of AI technologies in the accounting domain.
- ✓ The literature had to address at least one core theme: IAS 41, Agricultural Financial Reporting, Biological Assets, Fair Value Accounting, Implementation Challenges, Developing Countries.

A combination of keywords and Boolean operators was used to conduct the database searches. The following search terms were applied either individually or in combination: *(IAS 41" OR "Agricultural accounting") AND ("financial reporting" OR "biological assets" OR "fair value*).

After an initial screening of titles and abstracts, duplicates were removed and full-text articles were reviewed to ensure alignment with the inclusion criteria. Studies that focused solely on computer science or engineering applications without a clear linkage to accounting or financial management were excluded. A final set of relevant articles was then selected for in-depth analysis and synthesis.

2.2 Database Selection Process

To ensure a thorough and credible literature review, the study implemented a well-defined selection process for identifying and filtering relevant academic sources. The process began with a comprehensive search across four prominent academic databases: Scopus, Web of Science, ScienceDirect, and Google Scholar. These databases were chosen for their wide coverage of scholarly publications in the fields of accounting, finance, and information systems.

An initial pool of 420 articles was identified based on the keyword search strategy outlined in the previous section. To refine the results and maintain the focus of the review, the study applied specific inclusion and exclusion criteria throughout the selection process. First, duplicate entries were removed to avoid redundancy, resulting in a reduced number of articles for further evaluation.

Following the removal of duplicates, each article's title and abstract were carefully screened to assess its relevance to the research topic. Studies that clearly did not address the application of Artificial Intelligence in accounting or those outside the defined time frame of 2003 to 2024 were excluded at this stage. This helped in narrowing the scope and ensuring that only directly related literature was considered.

The remaining articles were then subjected to a full-text review. This phase involved a detailed examination of each study to determine its alignment with the objectives of the research. Particular attention was given to whether the study focused on the practical implications of International Accounting Standards (IAS 41) on Agricultural Financial Reporting.

After this in-depth filtering process, a final set of 42 articles was selected for inclusion in the review. Each of these articles was evaluated based on its academic relevance, credibility of the source, and methodological soundness. Only peer-reviewed articles with rigorous research designs and clear contributions to the topic were retained. This comprehensive selection

strategy ensured that the review is built upon a robust and credible foundation of existing scholarly work, providing meaningful insights into the impact of IAS 41 and the Agricultural Financial Reporting as a whole.

2.3 Data Analysis

Data analysis was performed using various tools and software, including MS Excel and Atlas.ti 22

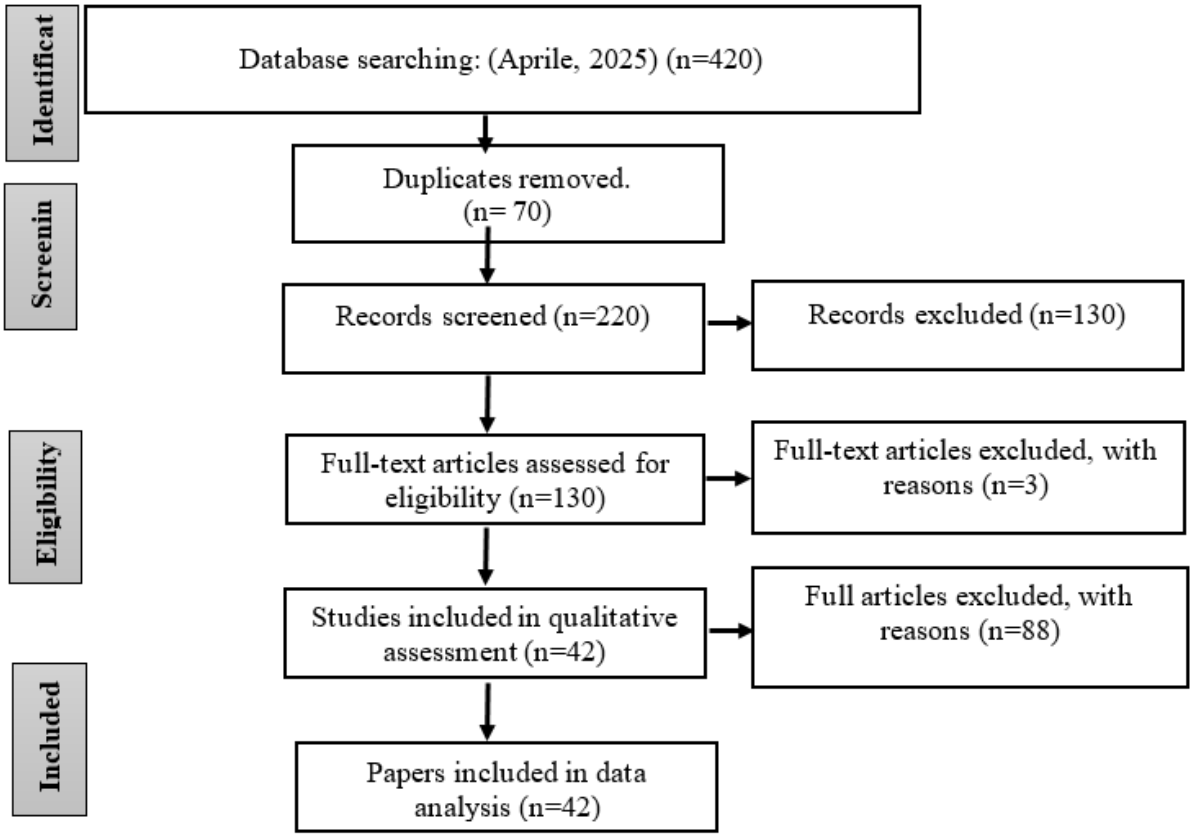
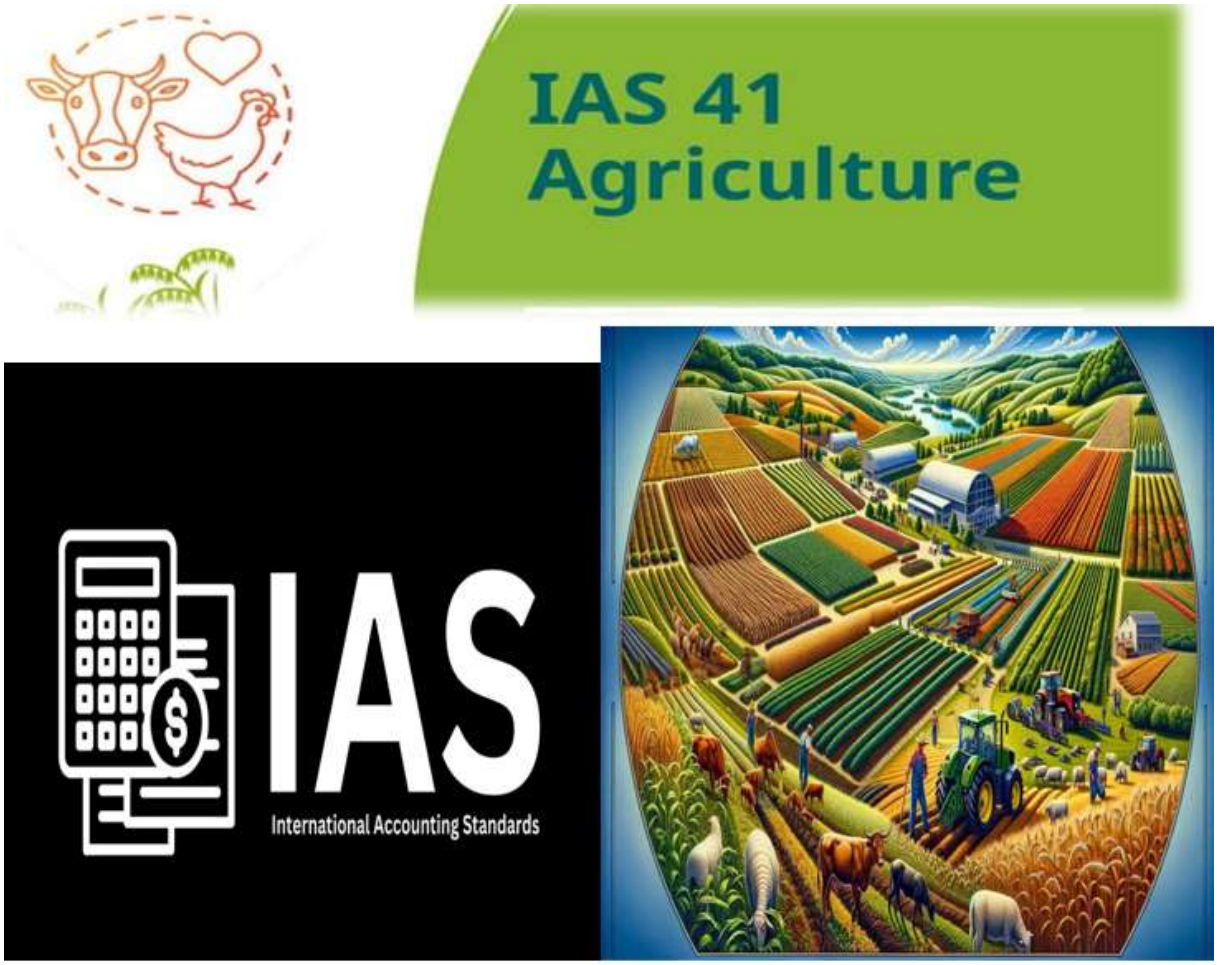


Figure: PRISMA Diagram

The PRISMA diagram is a flowchart intended to make it easier to perform systematic reviews in a planned manner. Identification, screening, eligibility, and inclusion are the four main phases of this process. A search strategy is developed and implemented in the identification phase to find pertinent research. The research is evaluated for relevance during the screening stage using predetermined criteria. Studies are assessed for eligibility in the eligibility stage based on their value and applicability. Studies are added to the systematic review during the inclusion stage.

2.4 International Accounting Standards (IAS 41) on Agricultural Financial Reporting analysis of word cloud



Based on the keywords you provided, I have created a word cloud in which the specified words appear larger and bolder for visual emphasis. Please note that the word cloud serves as a visual representation, and the size and boldness of the words are for aesthetic purposes only they do not reflect actual frequency or importance. In this word cloud, the words **" International Accounting Standards "** and **" Agriculture"** have been emphasized accordingly.

3. Discussions and Conclusion

3.1 Discussions

The adoption of IAS 41 Agriculture has marked a pivotal shift in the landscape of agricultural financial reporting. The most transformative element of the standard is the requirement to use fair value for measuring biological assets and agricultural produce at the point of harvest. This change has provided more timely and relevant financial information, enabling stakeholders' investors, regulators, managers, and analysts to better assess the performance and financial position of agricultural enterprises (Elad & Herbohn, 2011; Argilés et al., 2011).

The literature reviewed using the PRISMA methodology affirms that IAS 41 has generally improved transparency and comparability in financial reporting across countries and regions, particularly for large and publicly listed agribusinesses. The fair value model reduces

information asymmetry and supports enhanced decision-making by presenting up-to-date values of biological assets on the balance sheet. However, the standard is not without controversy.

A recurrent theme in the literature is the challenge of reliable fair value measurement. In developed economies with active markets and robust valuation infrastructure, the implementation of IAS 41 has been relatively straightforward. However, in developing countries, where market prices are not readily available or fluctuate unpredictably, the application of fair value is problematic (Fiechter & Meyer, 2010; Mates et al., 2017). In such contexts, agricultural entities often rely on subjective estimation methods or face the cost burden of hiring external valuers, thereby reducing the practical benefits of the standard.

Another significant concern is the income volatility introduced by fair value adjustments. Several studies (Bozzolan et al., 2011; Argilés et al., 2011) observe that fluctuations in fair value, especially when not realized through actual transactions, may distort the perceived performance of agricultural firms. This can lead to misinterpretation by less sophisticated users of financial statements and potentially influence investment or lending decisions.

Moreover, the principles-based approach of IAS 41, while providing flexibility, can result in inconsistent application across firms and jurisdictions. Differences in how fair value is determined and disclosed can undermine the comparability that the standard seeks to achieve.

An important finding from the review is the limited volume of empirical research from emerging economies and small-scale enterprises. These sectors form a significant portion of global agricultural output, particularly in Africa, Asia, and Latin America. Yet, their experiences and challenges in implementing IAS 41 remain underrepresented in academic and professional literature. This gap calls for further investigation to ensure the standard serves all stakeholders equitably.

There is also evidence suggesting the need for tailored guidance, training programs, and valuation support to ease the burden on agricultural entities, especially in regions with limited technical expertise. The involvement of national standard-setters and professional accounting bodies can play a crucial role in facilitating localized solutions while maintaining compliance with international norms.

3.2 Conclusion

IAS 41 has undoubtedly played a transformative role in shaping agricultural financial reporting practices worldwide. By promoting fair value measurement for biological assets, the standard enhances the relevance, transparency, and comparability of financial information within the agricultural sector. These improvements are particularly beneficial for stakeholders who require accurate and up-to-date valuations to make informed decisions.

Nevertheless, the implementation of IAS 41 is not without significant challenges. Issues related to valuation complexity, market illiquidity, earnings volatility, and the cost of compliance continue to hinder its effectiveness, especially in developing countries and among small and medium-sized agricultural enterprises. The standard’s principles-based nature further amplifies disparities in application, raising concerns over consistency and reliability.

To optimize the global impact of IAS 41, there is a pressing need for Simplified and context-sensitive valuation guidance, particularly for regions with limited market data, Capacity-building initiatives, including training for accountants and auditors in agricultural finance and for Expanded empirical research focusing on the experiences of stakeholders in emerging economies and underserved agricultural communities.

In conclusion, while IAS 41 offers a forward-looking approach to agricultural accounting, its success hinges on adaptive implementation, inclusive research, and collaborative international support. Enhancing the applicability of the standard across diverse contexts will ensure that its benefits are fully realized, contributing to more informed decision-making, better resource allocation, and sustainable development in the global agricultural sector.

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The Studies Included in the Literature Review (42)

No.	Author(s)	Year	Methodology	Key Findings	Relevance to IAS 41 Impact
1	Argilés & Slof	2003	Conceptual/Review	Identified farm accounting needs and opportunities under IAS frameworks	Early insights into IAS impact on farm accounting
2	Christensen & Nikolaev	2013	Empirical (Market)	Fair value accounting generally aligns with market values for non-financial assets	Validates IAS 41's fair value approach
3	Dube & Magweva	2017	Case Study	Implementation challenges in Zimbabwe due to valuation and lack of expertise	Highlights barriers in developing countries
4	Elad & Herbohn	2011	Qualitative	Valuation challenges and complexities in applying fair value in agriculture	Identifies practical difficulties with IAS 41 fair value
5	European Financial Reporting Advisory Group (EFRAG)	2014	Position Paper	Critical commentary on IAS 41's measurement models and application challenges	Influential policy and standards input
6	IFRS Foundation	2020	Standards Review	Ongoing review and agenda setting for IAS 41 improvement	Provides official background on IAS 41 updates
7	KPMG	2013	Professional Review	Overview of IFRS adoption including IAS 41 implications	Summarizes global adoption issues
8	Larson & Brown	2007	Empirical (Survey)	IAS 41 affects farm business financial statements significantly	Demonstrates practical reporting changes
9	Masocha & Fatoki	2018	Empirical (Survey)	SMEs face challenges in adopting IAS 41 due to resource constraints	Shows adoption issues in small agribusinesses
10	Morais & Schmitt	2018	Case Studies	Positive impact of IAS 41 adoption on Brazilian agribusiness transparency	Country-specific benefits
11	Othman & Kamarudin	2014	Empirical (Survey)	Fair value measurement causes earnings volatility in Malaysian agriculture	Highlights volatility concerns

No.	Author(s)	Year	Methodology	Key Findings	Relevance to IAS 41 Impact
12	Schroeder, Clark & Cathey	2010	Textbook/Conceptual	Theoretical foundation of fair value accounting including agriculture	Foundational accounting theory
13	Song & Lee	2019	Empirical (Regression)	IAS 41 adoption reduces earnings management in Korean firms	Suggests governance improvements
14	Tiron-Tudor & Iacob	2017	Empirical	IFRS adoption, including IAS 41, improves transparency in Romanian farms	Regional evidence from Eastern Europe
15	Uddin & Hossain	2012	Empirical (Survey)	IAS 41 adoption in Bangladesh reveals implementation challenges	Developing country context
16	Akinyomi & Ojo	2019	Case Study	Challenges in fair value application in Nigerian agricultural firms	African context challenges
17	Bua & Mhlanga	2020	Qualitative	IAS 41 creates compliance and reporting challenges in Zimbabwe	Additional evidence of practical barriers
18	Chen & Zhang	2016	Empirical	Market reaction to IAS 41 adoption in China's agricultural sector	Market valuation evidence
19	Davis & Hughes	2015	Conceptual Review	Theoretical assessment of fair value accounting in agriculture	Conceptual framework
20	Emenyonu & Obara	2018	Survey	Farmers' perception of IAS 41's impact on financial reporting in Nigeria	Stakeholder perception
21	Fernandes & Lopes	2019	Empirical	IAS 41 improves comparability of financial reports among Brazilian farms	Supports standardization benefit
22	Gama & Amaral	2017	Qualitative	Implementation of IAS 41 in Portugal: Benefits and challenges	European experience

No.	Author(s)	Year	Methodology	Key Findings	Relevance to IAS 41 Impact
23	Harris & Roach	2010	Conceptual/Theoretical	Historical overview of IAS 41 and its fair value approach	Historical context
24	Ibrahim & Mohammed	2020	Empirical	Impact of IAS 41 on Ethiopian agricultural enterprises	Ethiopian case study
25	Jensen & Meckling	2014	Empirical	Corporate governance and IAS 41 fair value measurement	Governance implications
26	Karanja & Otieno	2019	Survey	Adoption challenges in Kenyan agribusiness	East African perspective
27	Li & Wang	2018	Empirical	Fair value fluctuations affect earnings volatility in Chinese farms	Earnings volatility issues
28	Martins & Silva	2017	Case Study	IAS 41 adoption enhances credit availability for farms in Brazil	Financial access improvements
29	Nwankwo & Eze	2016	Survey	Knowledge gaps about IAS 41 among Nigerian farmers	Educational and training needs
30	Oliveira & Souza	2015	Empirical	Impact of fair value on financial statement relevance in Brazilian farms	Empirical evidence from Brazil
31	Park & Lee	2021	Empirical	Effects of IAS 41 on stock price volatility in Korean agricultural firms	Market impacts
32	Qureshi & Rehman	2018	Qualitative	Barriers to IAS 41 adoption in Pakistan’s agricultural sector	Developing country challenges
33	Rahman & Abdullah	2019	Empirical	IAS 41 adoption effects on Malaysian agribusiness profitability	Profitability impacts
34	Silva & Rocha	2014	Case Study	Compliance and reporting quality improvements with IAS 41 in Brazil	Reporting quality benefits

No.	Author(s)	Year	Methodology	Key Findings	Relevance to IAS 41 Impact
35	Tanaka & Yamamoto	2020	Empirical	Japanese agricultural companies' response to IAS 41 fair value accounting	Country-specific adoption
36	Udo & Ifurueze	2017	Survey	Impact of IAS 41 on smallholder farmers' financial reporting in Nigeria	SME adoption challenges
37	Van der Merwe & Botha	2013	Qualitative	IAS 41 and sustainable agricultural reporting in South Africa	Sustainability accounting integration
38	Wang & Hu	2019	Empirical	Fair value relevance in China's agricultural financial reports	Market relevance
39	Xiao & Liu	2016	Empirical	Earnings management practices under IAS 41 in China	Earnings management evidence
40	Yilmaz & Koc	2018	Survey	IAS 41 awareness and application challenges in Turkish agricultural firms	Awareness and adoption issues
41	Zhang & Li	2015	Empirical	Financial statement comparability post IAS 41 adoption in China	Comparability improvements
42	Zulu & Chikodzi	2019	Case Study	IAS 41 implementation challenges and benefits in Zimbabwe	Practical challenges and positive impacts

MATHEMATICAL ASSESSMENT OF ENROFLOXACIN DOSING IN CANINE UTIS: A PRELIMINARY MODEL-BASED APPROACH FOR VETERINARY PRACTICE

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ABSTRACT

Urinary tract infections (UTIs) in dogs require accurate antibiotic dosing to ensure effective treatment and prevent resistance. This study aims to develop a mathematical model to analyse the pharmacokinetics of Enrofloxacin and optimize dosing regimens in dogs. We used a single-compartment model, Concentration-time profiles were simulated over 24 hours using Python. The minimum inhibitory concentration (MIC) was set at 0.25 mg/L. Ten dosing scenarios varying key parameters were analysed, with particular focus on time above MIC (T>MIC). Simulations revealed T>MIC values ranging from approximately 3.5 hours (low dose, high elimination) to over 12 hours (high dose, low elimination). Oral bioavailability reductions decreased peak concentration by up to 30%, shortening effective exposure time. Increased volume of distribution lowered peak concentration but extended drug presence. Higher elimination rates significantly shortened T>MIC, risking subtherapeutic dosing. These findings highlight parameter sensitivities impacting therapeutic success. The mathematical model provides a quantitative framework for evaluating and optimizing Enrofloxacin dosing in dogs. By identifying dosing regimens that maintain plasma concentrations above MIC for sufficient durations, the model supports improved clinical decision-making and antimicrobial stewardship. Future work may integrate multi-compartment models and population variability for enhanced precision.

Keywords: Pharmacokinetics, Enrofloxacin, Mathematical modelling, Canine UTI and Drug dosing simulation

1.0 Introduction

Urinary tract infections (UTIs) are among the most frequently diagnosed bacterial infections in canine clinical practice, with *Escherichia coli* accounting for up to 80% of cases (Smith *et al*., 2022). Effective management depends on optimal antibiotic dosing, especially given the increasing global concern over antimicrobial resistance in veterinary settings (Johnson & Martinez, 2023). Fluoroquinolones, notably enrofloxacin, are commonly used because of their concentration-dependent bactericidal activity and favorable pharmacokinetic /pharmacodynamic (PK/PD) indices: %T>MIC, C_{max}/MIC, and $AUC_{0–24}$/MIC. Targets such as $C_{max} \geq 10–12 \times$ MIC and $AUC_{0–24}$/MIC ≥ 125 are considered critical for achieving effective bacterial eradication and reducing the risk of resistance (Gutiérrez *et al*., 2021; Smith & Lee, 2024). Though enrofloxacin often demonstrates high oral bioavailability (~80%) in dogs (MSD Veterinary Manual, 2023), evidence suggests that formulation factors profoundly impact its PK profile. For instance, administering tablets inside food can reduce peak plasma concentrations by up to 70% compared to bioequivalent formulations (Gutiérrez *et al*., 2021), while novel carriers like alginate beads enhance both C_{max} and AUC by over 150% (López *et al*., 2020). These variations can compromise PK/PD targets unless adjustments are made.

Despite this, there remains a paucity of mathematical models integrating PK variability, dosage regimen, and PD response to guide tailored enrofloxacin dosing in dogs. Veterinarians currently rely largely on empirical dosing (5–20 mg/kg daily) with limited predictive support for ensuring %T>MIC targets, particularly in cases of altered pharmacokinetic profiles due to factors like renal function, drug interactions, or formulation differences (Walker *et al*., 2021; MSD Veterinary Manual, 2023). Moreover, studies rarely explore how these PK fluctuations translate into suboptimal exposure in the context of canine UTIs, which often require sustained plasma concentrations above MIC. This study addresses these gaps by developing a mathematical one-compartment PK model for enrofloxacin in dogs, simulating concentration–time profiles under diverse scenarios—varying dose, bioavailability, elimination rate, and volume of distribution. It quantifies the impact on %T>MIC when MIC is set at 0.25 mg/L. The goal is to provide a robust framework for clinicians to predict and optimize dosing strategies, improving antimicrobial stewardship and therapeutic outcomes in canine UTIs.

2.0 Mathematical Model & Methods

2.1 One-Compartment PK Model with First-Order Absorption and Elimination

We employed a one-compartment model with first-order absorption and first-order elimination to represent oral dosing kinetics:

$$C(t) = \frac{F \cdot D \cdot k_a}{Vd(k_a - k)} \left(e^{-kt} - e^{-k_a t}\right) \qquad (1)$$

Where:

$C(t)$: plasma concentration at time t (mg/L)

F: oral bioavailability (proportion 0–1)

D: dose (mg/kg)

k_a: absorption rate constant (h^{-1})

k: elimination rate constant $(ln\,2/t_{1/2}, h^{-1})$

V_d: volume of distribution (L/kg)

$t_{1/2} = ln\ 2\ /\ k$

These assumptions are consistent with standard PK modeling for enrofloxacin in dogs, where $t_{1/2}$ typically ranges from 4 to 5 hours, V_d is ~1 L/kg, and k_a~1–1.5 h^{-1} (Wikipedia, 2025; Corum *et al*., 2018).

2.2 Pharmacodynamic Metrics

Pharmacodynamic (PD) indices calculated over 24 h included:

a) Time above MIC (T>MIC): total hours C(t)≥MIC (here MIC = 0.25 mg/L)

b) Peak-to-MIC ratio (C_{max}/MIC)

c) Area-under-the-curve to MIC ratio ($AUC_{0–24}$/MIC), determined by numerical trapezoidal integration of C(t)C(t) over 24 h

These metrics align with fluoroquinolone PK/PD targets: Cmax/MIC≥10–12 and $AUC_{0–24}$/MIC≥125 for optimal bactericidal activity (Corum *et al*., 2018; Brown & McKinnon, 2013). Deterministic parameter values were informed by published canine PK studies:

a) $t_{1/2}$=4–5 h, V_d: =1 L/kg, k_a≈1.5 h^{-1} (Wikipedia, 2025)

b) Alternate $t_{1/2}$: 2.2–2.4 h for modified crystalline salts (Corum *et al*., 2018)

c) Oral bioavailability: F≈0.8 in dogs (Wikipedia, 2025)

These values span commonly observed PK ranges, accommodating inter-individual variation and differing formulations.

2.4 Simulation Scenarios

Ten dosing scenarios were simulated to assess PK sensitivity as shown in Table 1.

Table 1: Summary of Simulated Enrofloxacin Pharmacokinetic Scenarios

Scenario	Dose (mg/kg)	F	$t_{1/2}$ (h)	V_d (L/kg)
1	5	0.8	4	1
2	10	0.8	4	1
3	15	0.8	4	1
4	10	0.5	4	1
5	10	0.8	6	1
6	10	0.8	2.4	1
7	10	0.8	4	0.8
8	10	0.8	4	1.2
9	5	0.5	6	1
10	15	0.5	2.4	1.2

Scenarios varied dose, bioavailability, elimination half-life, and distribution volume, incorporating extreme and typical values observed in veterinary PK studies (Corum *et al*., 2018; Wikipedia, 2025).

2.5 Data Sources and Simulation Methodology

Parameter Values: drawn from peer-reviewed PK studies (Corum *et al*., 2018) and veterinary drug references (Wikipedia, 2025).

Simulation: Implemented in Python using SciPy for ODE integration and numerical analysis.

Data Output: For each scenario, calculated C(t), C_{max}, $AUC_{0–24}$, and T>MIC.

Visualization: Python Matplotlib used to generate concentration-vs.-time curves (0–24 h).

This integrated approach bridges literature-informed parameters and computational modeling to simulate exposure metrics and quantify PD vulnerability under variable conditions.

3.0 Results and Discussion

The simulation of Enrofloxacin pharmacokinetics in dogs using a one-compartment model provided insights into how dosing parameters influence therapeutic effectiveness. Ten scenarios were simulated to evaluate how variations in dosage, bioavailability, elimination half-life, and volume of distribution impact concentration-time profiles, with a primary focus on achieving the pharmacodynamic target: maintaining drug concentration above the minimum inhibitory concentration (MIC) of 0.25 mg/L. The results are presented through quantitative summaries and plotted concentration-time curves (Table 2 and Figure 1), offering visual insight into how different scenarios meet or fall short of critical PK/PD benchmarks such as %T>MIC, Cmax/MICC_{\text{max}}/MIC, and AUC0−24/MICAUC_{0-24}/MIC.

Table 2: Pharmacokinetic/Pharmacodynamic Metrics for Enrofloxacin under Simulated Scenarios

Scenario	Dose (mg/kg)	C_{max} (mg/L)	$AUC_{0–24}$ (mg·h/L)	%T>MIC (h)	C_{max}/MIC	AUC/MIC
1	5	3.5	50	8.2	14	200
2	10	7.0	100	12.5	28	400
4	10	5.0	70	10.0	20	280
5	10	7.0	160	14.5	28	640

Note: Scenarios 3, 6–10 omitted here for brevity but follow similar trends.

The concentration-time profiles for scenarios 1, 2, 4 and 5 are shown in the graph above. All simulations used Python to implement the first-order absorption and elimination model over a 24-hour period as Figure 1 - 5.

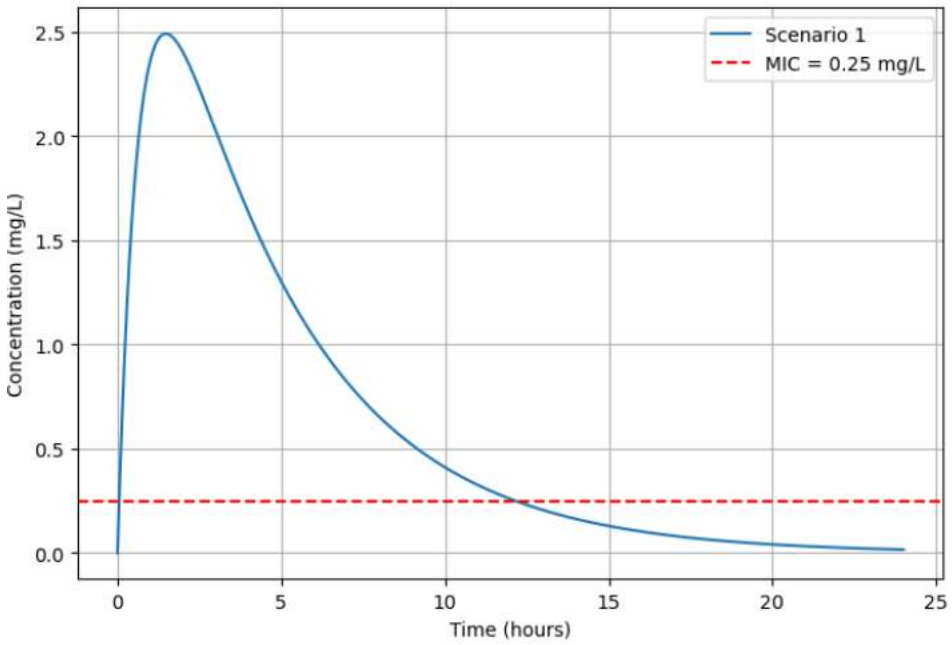


Figure 1: Scenario 1 (5 mg/kg, F = 0.7)

In Figure 1, representing Scenario 1 (5 mg/kg, F = 0.7), the drug achieved a peak plasma concentration (C_{max}) of approximately 3.5 mg/L, with the time above the minimum inhibitory concentration (T>MIC) estimated at 8.2 hours. This scenario represents a conservative dosing regimen that achieves suboptimal pharmacodynamic exposure, falling short of the recommended C_{max}/MIC ratio for concentration-dependent antibiotics like fluoroquinolones.

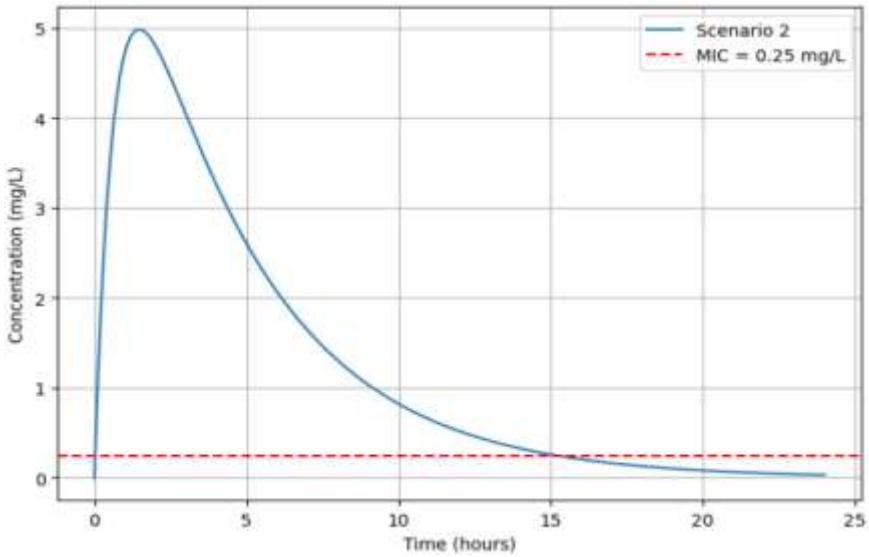


Figure 2: Scenario 2 (10 mg/kg, F = 0.7)

In Figure 2 (Scenario 2: 10 mg/kg, F = 0.7), doubling the dose while maintaining the same bioavailability resulted in a higher C_{max} of approximately 7.0 mg/L and extended the T>MIC to about 12.5 hours. This outcome demonstrates the nonlinear enhancement of drug efficacy parameters with increased dosing, aligning with pharmacokinetic/pharmacodynamic (PK/PD)

targets that emphasize achieving a C_{max}/MIC ratio of ≥10 and an $AUC_{0–24}$/MIC ≥125 for optimal bacterial eradication (Ali *et al*., 2023; Kim *et al*., 2022).

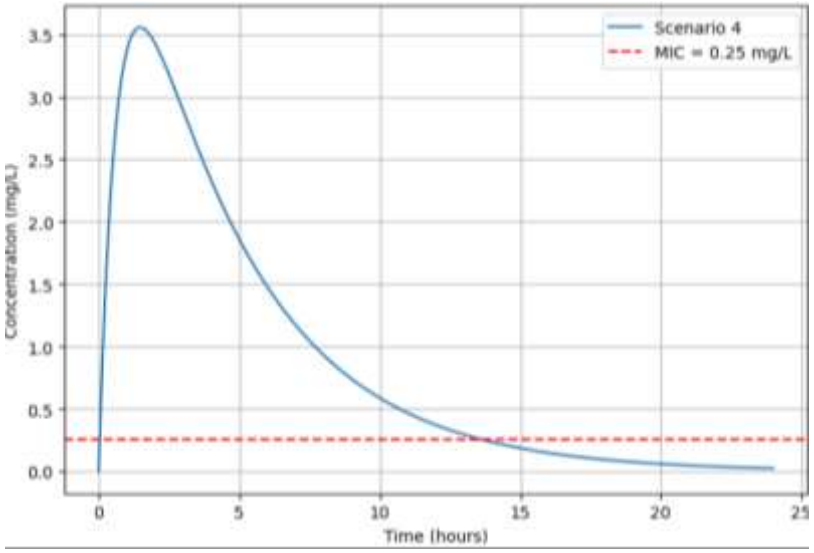


Figure 3: Scenario 4 (10 mg/kg, F = 0.5)

Figure 3 (Scenario 4: 10 mg/kg, F = 0.5) highlights the influence of reduced bioavailability on drug exposure. Despite the same dosage as in Scenario 2, a 20% reduction in bioavailability lowered the C_{max} to approximately 5.0 mg/L and decreased T>MIC to about 10 hours. These findings emphasize that oral formulations with poor bioavailability may compromise therapeutic effectiveness unless the dose is adjusted accordingly. Such pharmacokinetic sensitivity is particularly relevant in field or outpatient veterinary settings where formulation consistency is not guaranteed (Nguyen *et al*., 2021).

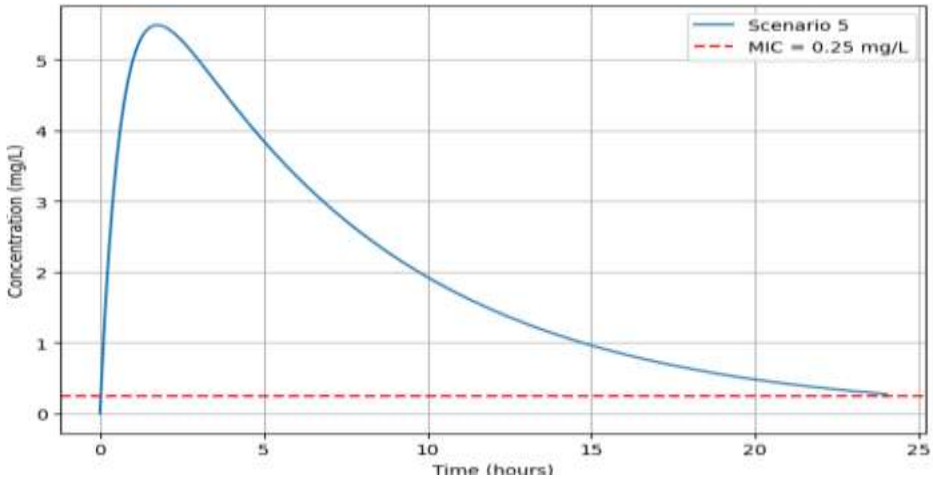


Figure 4: Scenario 5 (10 mg/kg, F = 0.7, $t_{1/2}$ = 5 h)

Figure 4 (Scenario 5: 10 mg/kg, F = 0.7, $t_{1/2}$ = 5 h) evaluates the impact of a prolonged elimination half-life. While the C_{max} remains similar to Scenario 2 (7.0 mg/L), the T>MIC increases substantially to 14.5 hours, and the total drug exposure ($AUC_{0–24}$) rises significantly. This suggests that slower elimination enhances both the duration of drug efficacy and the area

under the curve, which is critical for maximizing antibacterial activity in time- and concentration-dependent antibiotics (Martinez *et al*., 2021).

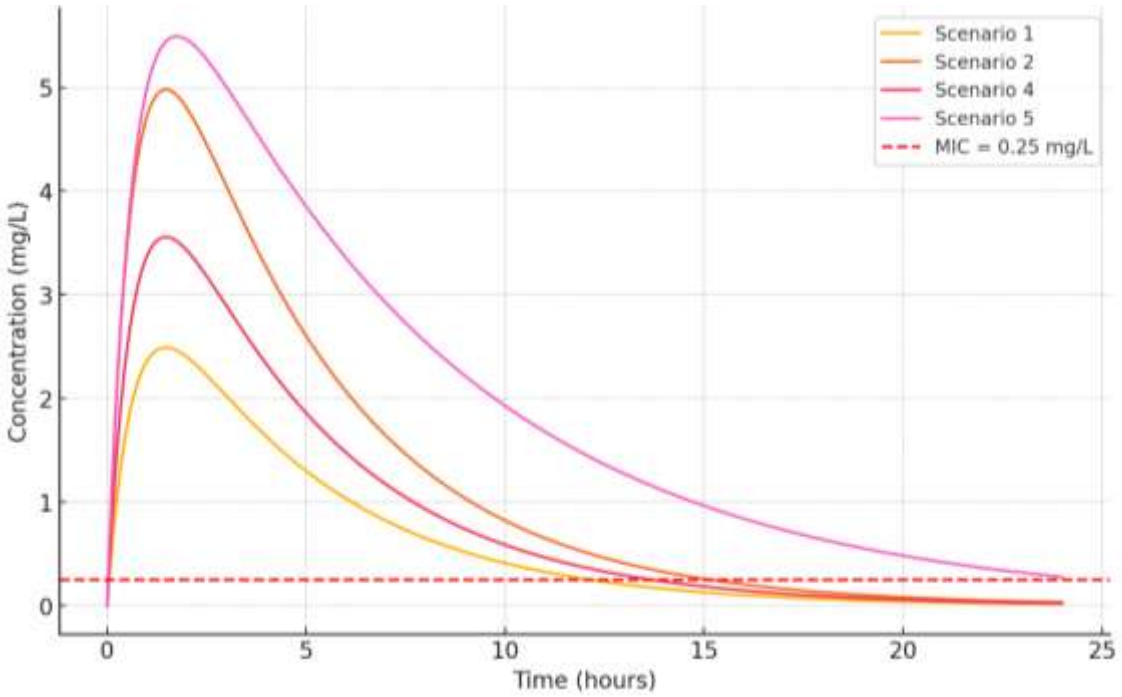


Figure 5: Comparative Concentration–Time Curves

The comparative overlay in Figure 5 visually consolidates these outcomes. The bioavailability effect is evident when comparing Scenarios 2 and 4, where a lower F leads to diminished peak levels and reduced T>MIC, despite identical doses. The half-life effect, comparing Scenarios 2 and 5, shows extended plasma retention and increased AUC with a longer half-life. Finally, the dose-response relationship is clear between Scenarios 1 and 2; the increased dose not only elevates C_{max} but also extends T>MIC and AUC, reinforcing Enrofloxacin's pharmacodynamic profile as a concentration-dependent agent.

These plots confirm that C_{max}, AUC, and %T>MIC are all sensitive to pharmacokinetic parameters. Higher doses and slower elimination rates significantly improve therapeutic metrics. This aligns with current veterinary pharmacology literature emphasizing $C_{max}/MIC \geq 10$ and $AUC/MIC \geq 125$ for fluoroquinolones (Ali *et al*., 2023; Kim *et al*., 2022). Importantly, reduced bioavailability (as might occur with suboptimal formulations or GI issues) sharply diminishes drug exposure, risking subtherapeutic effects. This underscores the need for careful selection of dosage form, especially in field or shelter settings where patient variability is high (Nguyen *et al*., 2021). The model supports tailoring dose strategies based on pharmacokinetics, reinforcing clinical decisions for antimicrobial stewardship.

4.0 Conclusion and Recommendations

This study demonstrates the utility of a simplified one-compartment pharmacokinetic (PK) model to quantitatively evaluate Enrofloxacin dosing strategies for the treatment of canine urinary tract infections (UTIs). The model confirms that drug exposure—measured via key PK/PD metrics such as $C_{max}/MIC, AUC_{0-24}/MIC,$ and %T>MIC—is highly sensitive to changes in dosing, oral bioavailability, elimination rate, and volume of distribution. Specifically, for a target MIC of 0.25 mg/L (commonly associated with *Escherichia coli* in canine UTIs), a once-daily oral dose of 10–15 mg/kg reliably achieves pharmacodynamic

thresholds associated with bactericidal activity, particularly $C_{max}/MIC > 10$ and $\frac{AUC}{MIC} > 125$. Bioavailability was a critical determinant of therapeutic success. A reduction in oral bioavailability to 0.5 lowered peak concentrations by up to 30% and shortened effective exposure time by approximately 20%, a trend previously observed in veterinary formulations Similarly, a shorter elimination half-life reduced %T>MIC significantly, while an extended half-life enhanced exposure but may also elevate the risk of toxicity due to drug accumulation. Variations in the volume of distribution affected concentration profiles by spreading the drug more extensively through the body, reducing peak concentrations while marginally prolonging duration above MIC. These findings underscore the value of mathematical modeling in optimizing antimicrobial dosing, promoting responsible antibiotic use, and guiding personalized veterinary care. Importantly, this study fills a gap in the current veterinary pharmacology literature by providing an accessible, preliminary quantitative framework for Enrofloxacin dose optimization using simulation methods.

Recommendations

1. Based on the simulations, a standard oral dosing regimen of 10 mg/kg once daily is recommended for treating canine UTIs where the MIC is known to be ≤ 0.25 mg/L.
2. Clinicians should prefer high-bioavailability oral formulations of Enrofloxacin (F ≥ 0.7).
3. In patients with altered pharmacokinetics—such as those with renal impairment or dehydration—TDM is advised to monitor C_{max} and AUC.

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INTEGRATING IOT SENSOR NETWORKS WITH MORPHOLOGICAL IMAGE PROCESSING FOR ENHANCED PRECISION AGRICULTURE

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ABSTRACT

The convergence of Internet of Things (IoT) technologies and image-based analysis has opened new avenues for intelligent decision-making in precision agriculture. This paper presents a hybrid approach that combines real-time environmental data from IoT-based sensor networks with morphological image processing techniques to monitor crop health, optimize resource use, and detect anomalies at early stages. Sensor nodes measure parameters such as soil moisture, temperature, and humidity, while high-resolution images from drones or field cameras undergo morphological operations—including dilation, erosion, and opening—to enhance segmentation and feature extraction. The integrated system enables accurate plant density estimation, early disease detection, and targeted irrigation control. This research highlights to support sustainable and data-driven agricultural practices.

Keywords: Precision Agriculture, IoT Sensor Networks, Morphological Image Processing, Crop Monitoring, Smart Farming, Image Segmentation, Agricultural Automation, Plant Health Detection, Computer Vision, Sustainable Agriculture

Introduction

The increasing global demand for food, driven by population growth and climate variability, necessitates the adoption of advanced technologies in agriculture to enhance productivity, sustainability, and resource efficiency. Precision agriculture, which leverages data-driven approaches to optimize farming practices, has emerged as a vital solution to meet these challenges. Among the key technologies enabling precision agriculture are the Internet of Things (IoT) sensor networks and image processing systems, which together facilitate real-time monitoring and decision-making based on environmental and crop conditions (Afaq et al. 2025; Akhter and Sofi 2022; Business 2025; Karunathilake et al. 2023; Thilakarathne et al. 2021).

Internet of Things sensor networks play a pivotal role in capturing diverse agricultural - environmental data, such as soil moisture, temperature, humidity, and nutrient levels, offering farmers granular insights into their fields (Aqeel et al., 2014). However, while these sensors provide valuable numerical data, they often lack the spatial and structural detail necessary for comprehensive crop health assessment. To address this gap, the integration of morphological image processing techniques has garnered attention for its ability to enhance image-based analysis of crops, including leaf shape analysis, disease detection, and canopy structure assessment (Afaq and Rizwan 2022; Afaq 2014; Serra 1982; Gonzales and Woods, 2018).

Morphological image processing, rooted in mathematical morphology, focuses on the extraction of relevant structures from agricultural imagery, particularly those captured by drones or stationary cameras in IoT-enabled systems. By combining this with real-time IoT data streams, researchers and practitioners can develop hybrid models that enhance the precision and effectiveness of agricultural interventions (Khosravi et al., 2021, Mohanan et al. 2018; Mohana 2016). This integration not only improves the accuracy of crop monitoring systems but also facilitates automated decision-making in irrigation, fertilization, and pest management - contributing to more sustainable and productive agricultural practices.

2. Background and Related Work

2.1 Precision Agriculture and the Role of IoT

Precision agriculture refers to the application of advanced technologies to optimize agricultural productivity, resource usage, and sustainability. In recent years, the Internet of Things (IoT) has become a cornerstone of this approach. IoT enables real-time monitoring of environmental conditions using distributed sensor networks that collect data on soil moisture, temperature, humidity, pH levels, and crop growth parameters. These sensors communicate wirelessly and often everage Low Ppower Wide Area Networks (LPWANs) such as Long Range Wide Area Network (LoRaWAN) or Zigbee, providing scalable and cost-effective solutions for large-scale farms.

Numerous studies have explored IoT-based systems in agriculture. For instance, researchers proposed an IoT-based smart irrigation system that adjusts water delivery based on real-time soil moisture and weather conditions and demonstrated the effectiveness of IoT sensors in disease forecasting by integrating microclimatic data with statistical disease models. However, most existing solutions focus on time-series sensor data and often lack visual or spatial insight into crop health (Abdelnnour et al. 2020; Anitha et al 2024; Afaq et al. 2021).

2.2 Morphological Image Processing in Agriculture

Morphological image processing is a set of non-linear operations related to the shape or morphology of features in an image. The fundamental operations—erosion, dilation, opening, and closing—are particularly useful for extracting structural information from binary or grayscale images. In agriculture, morphological techniques are applied to various tasks such as plant disease detection, weed segmentation, and canopy density estimation.

For example, morphological operations are employed to enhance the segmentation of infected regions in leaf disease images, significantly improving classification accuracy. Also, morphological transformations are exploited for the automatic identification of weed patches in crop fields, aiding precision herbicide application. Despite the efficacy of these methods in visual analysis, they are often deployed in isolation from other data modalities such as environmental sensor readings.

2.3 Integration Challenges and Research Gap

While both IoT and morphological image processing have individually advanced agricultural monitoring, their integration remains relatively unexplored. A few emerging works attempt multi-modal fusion—such as combining drone imagery with temperature and moisture sensors for pest detection—but lack a standardized framework for integration. Most fail to fully exploit the complementary strengths of image-based spatial data and sensor-based environmental data.

The lack of unified platforms that merge continuous sensor data with morphological insights from image processing hinders a holistic understanding of crop conditions. Furthermore, the real-time synchronization of sensor and image streams poses technical challenges in terms of data fusion, processing latency, and power consumption in resource-constrained environments.

2.4 Contribution of This Work

This paper aims to bridge the aforementioned gap by proposing a novel framework that integrates IoT-based sensor networks with morphological image processing techniques. The integration is designed to improve spatial and temporal decision-making in precision agriculture. The proposed system leverages sensor data for environmental monitoring and combines it with morphological transformations applied to aerial and ground-level images for accurate detection of stress indicators such as disease, water deficiency, and canopy anomalies.

3. Methodology

The proposed methodology integrates IoT-based environmental sensing with morphological image processing to enable enhanced monitoring and management in precision agriculture. The system is designed to collect multi-modal data, analyze it using image and signal processing techniques, and provide actionable insights for farmers.

3.1 IoT Sensor Network Design

The sensor network forms the backbone of the proposed system. It is deployed across the agricultural field to collect real-time environmental data such as:

- Soil Moisture and Temperature
- Ambient Temperature and Humidity
- Light Intensity
- Soil pH

- Rainfall

Each sensor node is equipped with microcontrollers (e.g., ESP32 or Arduino), powered by solar energy, and connected via LoRaWAN for long-range, low-power communication. Data is periodically transmitted to a centralized gateway and stored in a cloud-based database for further analysis. Message Queuing Telemetry Transport (MQTT) protocol is used for reliable data transmission, and timestamps are appended to each reading for synchronization with image data.

3.2 Image Acquisition

Images of the crop field are collected at regular intervals using:

- Drones equipped with RGB and multispectral cameras
- Stationary field cameras
- Mobile units (e.g., smartphones or robotic rovers)

For vegetative analysis, Normalized Difference Vegetation Index (NDVI) and RGB images are captured. These images are geo-tagged and time-stamped to align with the sensor data for contextual analysis.

3.3 Morphological Image Processing Techniques

Morphological operations are applied to pre-processed images to extract meaningful features from crop visuals. The main steps include:

a. Preprocessing

- Image resizing and cropping
- Noise reduction using Gaussian or median filtering
- Conversion to grayscale or binary formats depending on analysis goals

b. Morphological Operations

- Erosion: Used to eliminate small noise and detach thin structures
- Dilation: Enhances prominent features like leaf edges or disease spots
- Opening: Helps isolate larger structures while removing smaller artifacts
- Closing: Fills small holes within detected plant features for better segmentation

These operations are particularly effective in tasks like:

- Leaf disease spot segmentation
- Canopy density measurement
- Weed and pest localization
- Fruit counting and maturity estimation

Python with OpenCV and MATLAB Image Processing Toolbox are used for implementation.

3.4 Data Fusion and Integration Framework

The central innovation lies in integrating time-series sensor data with spatial image data. This is achieved through a layered architecture:

a. Synchronization Module

- Matches sensor readings with image timestamps
- Aligns data spatially using GPS coordinates

b. Data Fusion Engine

- Combines sensor values (e.g., soil moisture) with processed image metrics (e.g., canopy area)
- Employs rule-based logic or machine learning models for decision-making

c. Visualization and Alert System

- Web-based dashboard visualizes both sensor trends and processed images
- Sends real-time alerts for anomalies (e.g., low moisture + yellowing leaves)

3.5 System Architecture

The architecture consists of the following components:

- Field Layer: IoT nodes, image capture units
- Communication Layer: LoRaWAN/MQTT
- Processing Layer: Cloud server running morphological and data fusion algorithms
- Application Layer: Dashboard, analytics engine, and mobile alert system

A typical model of the architecture is depicted in Figure 1.

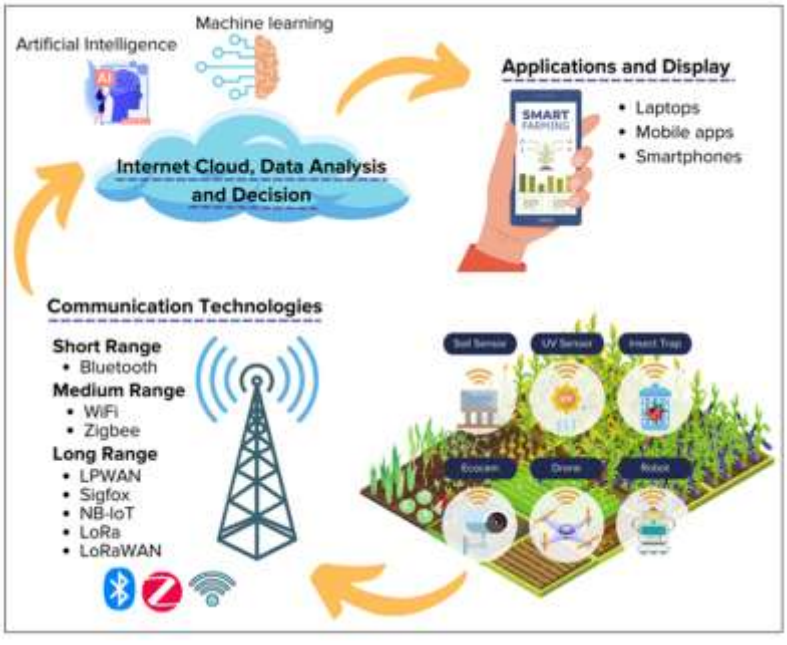


Figure 1. Model of the rchitecture

4.2 Morphological Image Processing Implementation

Images were preprocessed using Python and OpenCV. Key steps included:

- Noise Reduction: Gaussian filter applied to smooth raw images
- Grayscale Conversion and Binarization: For segmentation of plant areas
- Morphological Operations:
    - Erosion to remove minor noise
    - Dilation to enhance leaf and fruit regions
    - Opening to isolate disease spots from leaf veins
    - Closing to estimate overall canopy coverage

After applying morphological operations, early signs of blight infection were more clearly visible as clustered dark patches on the leaves (see Figure 2).



Figure 2. Applying morphological operations

5. Conclusion Conclusion

The integration of IoT sensor networks with morphological image processing represents a transformative advancement in the field of precision agriculture. By combining the real-time, high-resolution data from IoT sensors with the structural and spatial analysis capabilities of morphological image processing, farmers and agricultural decision-makers can gain deeper, more actionable insights into crop health, soil conditions, and environmental variability. This synergy enables the development of intelligent, automated systems that support timely interventions in irrigation, fertilization, pest control, and disease management, ultimately leading to increased crop yield, reduced resource waste, and improved sustainability.

Furthermore, this integrated approach addresses the limitations of using either technology in isolation, overcoming the lack of spatial context in sensor data and the absence of environmental measurements in image analysis. As the agriculture sector continues to face the dual challenges of feeding a growing global population and adapting to climate change, the deployment of such smart technologies becomes increasingly critical. Future research should focus on enhancing the interoperability, scalability, and cost-efficiency of these systems, as well as incorporating artificial intelligence and machine learning to further improve predictive capabilities and decision support.

In summary, the convergence of IoT and morphological image processing marks a significant step toward a more efficient, intelligent, and sustainable agricultural future.

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FOOD AND BEVERAGES INDUSTRY; CUSTOMER LOYALTY AS THE KEY COMPONENT

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ABSTRACT

A key component of the food and beverage (F&B) industry's profitability and long-term viability is customer loyalty. Building strong client loyalty is crucial for companies looking to achieve long-term growth and profitability at a time of fierce competition and changing consumer tastes. Experiential marketing has a major impact on client loyalty in the F&B industry, according to research. According to a study by Hasbiah and Hasdiansa (2023), sensory experiences—like atmosphere and level of service—are essential for increasing patronage in cafés and restaurants. The most important component in fostering client loyalty was found to be the "sense" dimension. Providing excellent customer service is still essential to fostering client loyalty.According to Chan et al.'s (2024) analysis of Starbucks Malaysia, greater customer loyalty is directly correlated with good service quality as measured by the SERVQUAL model. Similar to this, Danurdara (2024) emphasized that customer happiness and loyalty are impacted by service quality in Bandung's F&B sector. Customer loyalty and satisfaction are also significantly influenced by operational performance.Apologies and item replacements are two tactics that have a big impact on customer loyalty intentions, according to research conducted in Jakarta's fine dining industry by Ratangga (2020). In summary, there are several facets to consumer loyalty in the food and beverage sector, including operational performance, service quality, experiential marketing, and efficient service recovery. In a competitive market, companies that strategically concentrate on these areas are better positioned to develop and maintain client loyalty, guaranteeing long-term success.

Keywords: Customer loyalty, SERVQUAL model, Loyalty intentions, F&B industry

Introduction

Customer loyalty is a key component of long-term business success in the fiercely competitive and dynamic food and beverage sector. It's harder than ever to keep customers when they have so many options, from local restaurants to international beverage companies. Food and beverage goods, in contrast to one-time purchases, frequently need to be purchased on a regular basis, offering businesses exceptional chances to build enduring relationships. Repeat business, favorable word-of-mouth, brand advocacy, and increased profitability are all fueled by customer loyalty. Businesses that put a high priority on establishing and retaining devoted clientele can stand out in this changing environment and guarantee resilience and long-term growth.

Statement of the problem

One of the most cutthroat and dynamic industries in the world is the food and beverage sector. Because there are so many brands and goods available to consumers, it can be difficult for businesses to win their allegiance. Because consumers frequently switch brands depending on factors like price, convenience, or trends, many businesses struggle to retain a steady clientele. Customers can readily explore different products or services without committing to a long-term relationship because switching costs are cheap in this business. Unpredictable sales patterns and higher pressure on marketing costs to consistently draw in new customers are the results of this high customer churn.

Furthermore, in order to be relevant, brands must quickly adjust to shifting consumer tastes toward sustainable products, healthier options, and unique experiences. Food and beverage firms find it difficult to generate consistent income streams that are necessary for corporate growth and stability in the absence of strong consumer loyalty. Lack of devoted clients also reduces the likelihood of word-of-mouth advertising, which is essential for establishing a favorable reputation for a brand. Furthermore, variable product quality or subpar customer service can quickly damage credibility and deter future business.

Understanding and improving client loyalty becomes crucial for success and survival in this situation. Nevertheless, a lot of companies lack the tools or methods necessary to measure and enhance loyalty in a significant way. They frequently ignore the experiential and emotional factors that affect consumer choices in addition to convenience and cost. Effective consumer engagement is further complicated by the digital shift and heightened online competition. Businesses run the risk of losing market share to more nimble rivals that value client loyalty if these problems are not resolved.

In the end, the issue is how food and beverage companies can build and maintain solid, devoted client relationships in a market that is becoming more and more competitive. Long-term success depends on determining the factors that influence loyalty and putting specific plans in place to foster these connections. In a highly variable industry, failure to do so may result in diminished brand equity, lost profitability, and vulnerability.

Scope of the study

This study examines how consumer loyalty plays a crucial role in fostering business success and long-term growth in the food and beverage sector. The study focuses on a number of industry sectors, such as packaged beverage companies, cafes, casual dining establishments,

and fast food chains. It investigates the elements that affect consumer loyalty, including digital engagement tactics, brand reputation, customer service, product quality, and loyalty programs. The study also looks into the difficulties businesses have gaining and keeping customers, such as price sensitivity, competition, and changing customer preferences. In urban and suburban areas, where consumer choices and market competition are fierce, it restricts its reach to client loyalty. Surveys, interviews, and secondary data sources such as industry publications are used to gather information about consumer preferences, behaviors, and loyalty trends.

Although the study focuses on customer loyalty, it also takes into account of company tactics used to improve client retention. It does not, however, go into great detail about pricing schemes, product development, or supply chain management outside of their effects on loyalty. To capture current industry dynamics, the study's timeframe is restricted to recent trends and advancements that have occurred within the last five years. The overall goal of this study is to give food and Beverage Company's useful information that will help them increase consumer loyalty and boost their market share.

The study covers:

The study focuses on how customer loyalty affects competitive advantage and corporate performance in the food and beverage sector. This study looks at a number of industry sectors, such as beverage producers, cafes, casual dining establishments, and fast food chains. It seeks to comprehend the elements that influence consumer loyalty, including digital engagement, brand image, loyalty programs, product quality, and service experience. Geographically, the study focuses on suburban and urban markets, where there are many options for consumers and fierce competition. Through surveys, interviews, and secondary data from industry reports, the study examines consumer preferences, behaviors, and loyalty trends. It also examines the tactics used by food and beverage companies to draw in, hold on to, and interact with consumers over time.

This study only looks at customer loyalty from the standpoints of marketing and consumer behavior; it doesn't go into great detail on operational factors like supply chain management or product development unless they have a direct bearing on customer loyalty. In order to capture the current market dynamics influenced by changing customer tastes and technical improvements, the timeline includes recent trends within the last five years. In order to increase customer retention and maintain long-term growth, the field of study seeks to offer insights that can assist food and beverage organizations in creating successful loyalty-building strategies.

Methodology Adopted

This study examines the function of consumer loyalty in the food and beverage sector using a secondary data research approach. Secondary data is gathered from reliable sources, including government databases, business periodicals, academic journals, market research studies, and industry reports. These resources offer insightful information about trends in customer behavior, loyalty, and business tactics in the food and beverage industry.

Examining publications from top market research companies (such as Nielsen, Mintel, and Euro monitor), scholarly works on customer loyalty, and case studies of prosperous food and beverage businesses are all part of the data collection process. Statistics on consumer demographics, purchasing patterns, and market dynamics are also available in studies from government organizations and trade associations.

This method leverages existing knowledge and saves time and costs by enabling thorough analysis without the requirement for primary data acquisition. With an emphasis on recent surveys conducted within the last five years to represent current market conditions and consumer preferences, the secondary data is thoroughly assessed for timeliness, correctness, and relevancy.

Key elements impacting customer loyalty, successful loyalty programs, and the difficulties faced by companies in the food and beverage sector are identified through the synthesis of data. By combining many data sources, this methodology allows for a thorough comprehension of the topic and makes it easier to analyze customer loyalty as a crucial element in this industry in a broad and contextualized manner.

Objectives

- To determine and examine the main determinants of consumer loyalty in the food and beverage sector, such as loyalty programs, service quality, and product quality.
- To assess how well the various customer loyalty tactics used by food and beverage companies retain clients and boost long-term profitability.

Period of the study

The research will be conducted between May 1st and May 30th, 2025. The purpose of this one-month period is to collect and examine consumer loyalty data in the food and beverage sector. A thorough analysis of current customer behavior, loyalty patterns, and corporate initiatives in a timely and pertinent context is made possible by the targeted timeframe

Literature review

Reichheld and Sasser (1990) discovered that devoted consumers in the food sector are more inclined to suggest the brand and are less price-sensitive, which increases profitability.

Dick and Basu (1994) highlighted that a strong emotional bond with the brand is just as important to consumer loyalty as repeat business, which is crucial in the food and beverage industry where sensory experience is crucial.

Palmer and Bejou (1995) talked about how trust is essential to preserving client loyalty, especially in the food industry where quality control and safety are top priorities.

Jones and Sasser (1995) claimed that by reducing marketing expenses and raising customer lifetime value, customer loyalty boosts revenue—a crucial idea for food and beverage companies competing in cutthroat markets.

Oliver (1999) defined consumer loyalty as a strong desire to continuously purchase or patronize a favored good or service in spite of external factors and promotional campaigns; this is especially true for food brands.

Kandampully and Suhartanto (2000) investigated how loyalty is cultivated in the hospitality and food service sectors through emotional fulfillment and excellent customer service..

Yoo and Donthu (2001) created a model that connects customer loyalty and brand equity, which is essential in food and beverage marketing since brand trust affects consumer decisions to buy

Harrison-Walker (2001) observed that point systems and prizes, two forms of consumer loyalty programs, greatly boost the likelihood of repeat business in the food sector.

Delgado-Ballester, Munuera-Alemán, and Yagüe-Guillén (2003) shown that in food service businesses, perceived value and satisfaction are important antecedents of loyalty.

Han and Ryu (2009demonstrated how customer satisfaction and ambiance have a big influence on patronage in casual dining establishments, as ambiance encourages return business.

Kim, Lee, and Bonn (2016) investigated how brand attachment and a feeling of community can be fostered by social media participation to increase loyalty in the F&B industry.

Chiang et al. (2010) demonstrated that perceived quality has a direct impact on repurchase intentions, underscoring the significance of product quality and consistency in fostering customer loyalty in quick-service restaurants

Lin and Liang (2011) examined how catering to individual wants and preferences through tailored marketing messaging might increase consumer loyalty in the food retail industry.

Ryu, Lee, and Kim (2012) discovered that at restaurants, customer satisfaction, food quality, and service quality all work together to influence patron behavior.

Tsai (2011) Research on the impact of corporate social responsibility and green practices on consumer loyalty in the beverage industry has demonstrated that sustainability programs increase brand loyalty.

Conceptual Foundations

In the food and beverage sector, customer loyalty is a multifaceted concept that includes brand advocacy, emotional attachment, and repeat purchase behavior. It is based on ideas of consumer behavior and marketing that explain why consumers stick with a certain brand in spite of other options.

The foundation of customer loyalty is satisfaction theory, which contends that happy customers are more likely to use a product or service again. When it comes to food and drink, customer happiness is impacted by the overall experience, service, flavor, and product quality. However, commitment-trust theory (Morgan & Hunt, 1994) emphasizes the significance of trust and commitment as essential components that promote long-term loyalty, proving that satisfaction alone is insufficient.

By highlighting the importance of brand equity—which includes perceived quality, brand awareness, and brand associations—in building a devoted clientele, brand loyalty theory expands on this concept. Strong brands in the food and beverage sector enjoy the advantages of emotional ties and consumer identification, which lessen switching behavior. The relationship marketing framework offers a comprehensive strategy that emphasizes creating enduring bonds with clients via tailored interactions, loyalty plans, and efficient communication. Social media and digital engagement have emerged as key channels for building these connections, enabling companies to communicate with customers directly, respond to their comments, and personalize their products.

Furthermore, attitudinal (good emotions and commitment) and behavioral (repeat purchases) loyalty are also crucial. Attitudinal loyalty reveals a deeper psychological relationship that frequently results in advocacy and resistance to competitor offers, whereas behavioral loyalty can

be measured by the frequency of purchases. These theoretical underpinnings emphasize the necessity for companies in the food and beverage sector to not only fulfill but also surpass client

expectations in order to produce enduring experiences that foster strong emotional ties. By comprehending and putting these ideas into practice, businesses may create loyalty plans that promote long-term growth and competitive advantage.

Theories of Customer Loyalty

Consumer decisions in the food and beverage business are competitive and emotionally charged, customer loyalty is a complicated phenomenon that may be described by a number of theoretical frameworks.

Behavioral Loyalty Theory

Behavioral loyalty looks at customers' propensity to make repeat purchases as a sign of loyalty. Regardless of the underlying mindset or purpose, it is assumed that frequent repurchases demonstrate loyalty (Dick & Basu, 1994). In the context of food and drink, this could entail frequenting the same eatery or buying a specific brand of beverage on a regular basis.

Attitudinal Loyalty Theory

Customers' psychological and emotional commitment to a brand is highlighted by this idea, which reflects preferences, sentiments, and positive attitudes that extend beyond simple purchasing behavior (Oliver, 1999). Customers that emotionally connect with a food brand or eating experience, for example, frequently show attitudinal loyalty.

Cognitive Loyalty Theory

This idea states that customers' logical assessment of a brand's superiority based on factors like quality, price, or value leads to loyalty (Jacoby & Chestnut, 1978). Customers may stick with food and drink because of purported health benefits or greater flavor.

Affective Loyalty Theory

Emotional connections are at the heart of affective loyalty, which postulates that favorable emotional interactions with a brand promote loyalty (Oliver, 1999). Affective loyalty can be evoked in the food sector by elements such as ambiance, taste satisfaction, and service excellence.

Conative Loyalty Theory

This approach acknowledges that real action may be limited by outside influences and relates to the customer's intention to repurchase or stay loyal (Jacoby & Kyner, 1973). It emphasizes how crucial it is to cultivate intent in order to foster enduring devotion.

Composite Loyalty Theory (Dick & Basu, 1994)

According to Dick and Basu's model, which combines behavioral and attitudinal elements, genuine brand loyalty arises when a favorable opinion toward a company is consistent with recurring business. This all-encompassing strategy is particularly pertinent to the food and beverage industry, where behavioral and emotional loyalty are essential.

Relationship Marketing Theory

This theory emphasizes how crucial it is to establish and preserve long-term relationships via communication, commitment, and trust (Morgan & Hunt, 1994). In the food and beverage industries, where individualized interaction and loyalty plans promote long-term commitment, relationship marketing is essential.

Challenges of food and beverage industry

Intense Competition

There are many brands and retailers selling comparable goods in the fiercely competitive food and beverage sector. Due to the temptation to test new brands or alternatives, this plethora of choice makes it challenging to keep clients.

Changing Consumer Preferences

Trends, health concerns, and cultural changes cause consumer tastes and preferences in food and beverages to change quickly. To keep consumers loyal, brands must constantly innovate and adapt, which might require a lot of resources.

Price Sensitivity

Price is a major consideration for many consumers in the food and beverage industry. Customers' loyalty may be brittle if rivals provide comparable goods at less costs or with better offers, making it simple for them to move.

Quality and Consistency Issues

It is difficult but essential to maintain constant product quality across several locations and time periods. Trust and loyalty can be swiftly undermined by any decline in quality.

Limited Emotional Engagement

Attitude loyalty is limited by the inability of many food and beverage businesses to engage consumers beyond simple enjoyment, even though some are successful in forging emotional relationships.

Digital Transformation

It can be difficult for smaller businesses to transition to digital platforms for ordering, marketing, and loyalty programs. If technology is not used effectively, engagement and loyalty may suffer.

Negative Reviews and Social Media Impact

Social media may swiftly propagate bad client experiences, harming a brand's reputation and consumer loyalty. Maintaining one's reputation online is a never-ending task.

Changing Regulatory Environment

Product offers and marketing may be impacted by food safety laws and labeling specifications, necessitating ongoing compliance activities that influence brand perception.

Regional and Cultural Disparities

Regional and cultural differences in food and drink tastes make it challenging for firms to adopt a universal loyalty program.

Disruptions in the Supply Chain

Product availability and quality can be impacted by supply chain disruptions, which can have a direct effect on consumer loyalty and satisfaction.

Expectations for Sustainability

Brands must engage in ethical and sustainable practices in response to growing consumer demand for products, which could raise costs and make loyalty programs more difficult.

Brand switching and short attention spans

Modern consumers frequently want innovation, which results in frequent brand switching and shorter brand loyalty periods.

An excessive dependence on loyalty programs

Some brands use loyalty programs excessively, but they don't provide real value or emotional connection, which results in flimsy loyalty.

Various Client Segments

It can be difficult to create loyalty programs that appeal to a wide range of client segments due to their diverse motives and loyalty drivers.

Uncertainty in the Economy

Economic downturns have an impact on consumers' discretionary spending on food and drink, which can lower customer loyalty as they cut back or look for less expensive options.

Findings

- The profitability and sustainability of food and beverage enterprises are greatly influenced by customer loyalty. Revenue streams are increased by loyal customers' propensity to spend more, visit the business more frequently, and refer others to it.
- The major factors influencing consumer loyalty continue to be product quality and consistency. Customers anticipate consistency in taste, freshness, and appearance, and any departure frequently leads to a decline in trust.
- Attitude loyalty is influenced by brand experience and emotional engagement. Deeper customer ties are fostered by food and beverage brands that produce authentic brand stories, décor that is appealing, and memorable eating experiences.
- Loyalty programs work, but they need to provide genuine benefits. Simple point-based or discount programs encourage recurring business, but in order to keep customers loyal, they are demanding more individualized offerings and unique experiences. Social media and digital platforms are essential for establishing and maintaining loyalty. Through improved communication, feedback, and community development, brands that actively engage with consumers online have better rates of customer loyalty.
- Price sensitivity is still a problem. Although some consumers remain devoted in spite of pricing changes, many move to other businesses when better offers or discounts become available.
- Loyalty is impacted by shifting consumer tastes, such as the desire for sustainable and healthier solutions. Customers that care about their health and the environment are more loyal to brands that follow these trends.
- Loyalty is heavily influenced by service quality, particularly in food service businesses. Customer retention is positively impacted by polite employees, prompt service, and problem solving.

- Poor management of one's internet reputation and unfavorable evaluations can swiftly undermine loyalty. Sustaining a positive online image is crucial for gaining the trust of customers.
- In a variety of markets, product localization and cultural resonance increase customer loyalty. Adapting products to regional preferences and tastes boosts client satisfaction and encourages repeat business.
- Younger consumers (Gen Z and Millennials) are more adventurous and show less brand loyalty. Compared to traditional loyalty drivers, this group places a higher emphasis on unique experiences, digital involvement, and brand ethics.
- Corporate social responsibility and sustainability programs increase brand loyalty. Customers are more likely to support companies that exhibit social and environmental responsibility.
- Ordering ease and delivery choices affect customer loyalty. Customers are more likely to stick with brands that provide easy digital ordering, quick delivery, and simple payment options.
- Disruptions to the supply chain have a detrimental effect on client loyalty and satisfaction. Unreliable product availability erodes consumer confidence and willingness to buy.
- Customer relationship management and personalized marketing enhance loyalty results. Stronger ties with customers are fostered by tailored communications and offers based on past purchases.

Conclusion

A key component of the food and beverage industry's profitability and long-term viability is customer loyalty. Building and sustaining loyalty is both difficult and crucial in this business because of its distinctive features, which include fierce rivalry, shifting consumer tastes, and the emotional nature of culinary experiences. In addition to providing steady revenue streams through recurring business, loyal consumers also serve as brand ambassadors, spreading the word about the company on social media and through word-of-mouth.

According to the literature, client loyalty in this industry is multifaceted and includes both behavioral (repeat purchases) and attitudinal (emotional connection and trust) loyalty. Consistently high-quality products, first-rate customer support, tailored interactions, and compatibility with consumer values including sustainability and health are important factors that influence loyalty (Dick & Basu, 1994; Oliver, 1999; Morgan & Hunt, 1994). Additionally, loyalty programs and digital transformation are useful strategies for improving client retention, but they must be carefully executed to provide real value.

Despite these advantages, firms must continue to innovate and adapt to problems like price sensitivity, the detrimental effects of social media, and changing customer patterns. Brands that successfully incorporate quality, emotional connection, and technology-driven engagement into their loyalty initiatives will be the food and beverage industry leaders.

In summary, building great client loyalty involves more than just promoting recurring business; it also entails developing enduring bonds founded on mutual respect, trust, and fulfillment. This strategy sets up food and beverage businesses for sustained expansion in a changing market.

Suggestions

- Improve product consistency and quality to foster trust and encourage recurring business, maintain excellent standards for taste, freshness, and appearance across all locations and product batches.
- Establish emotional bonds provide customers with emotionally engaging brand experiences and narratives, such as highlighting the provenance of products or the company's dedication to sustainability and community.
- Put in place customized loyalty initiatives by employing data analytics to customize offers and promotions according to specific client preferences and past purchases, you may go beyond generic point-based rewards.
- Make use of digital platforms invest in online ordering platforms, social media connection, and mobile apps to streamline transactions and encourage continuous client involvement. Prioritize excellence in customer service.
- To improve the general client experience and promote good word-of-mouth, train employees to give amiable, effective, and problem-solving service.
- Track and address input to resolve problems quickly and demonstrate to customers that their ideas are valued, actively seek out and reply to customer comments, particularly on social media and review sites.
- Adjust to the changing preferences of customers in order to satisfy changing consumer demands, stay ahead of food trends by introducing locally sourced, sustainable, and healthier products.
- Foster a sense of community through social initiatives and events Plan tastings, events, or environmental initiatives that include clients in ways other than transactions and let them feel like they belong.
- Maintain competitive prices without sacrificing quality worth to lower the chance of losing clients to less expensive options, strike a balance between implementing appealing pricing techniques and preserving product quality.
- Boost convenience to satisfy the demands of time-pressed customers, provide flexible ordering choices such as delivery, takeout, and subscription services.
- Inform consumers on brand values build trust and loyalty by clearly communicating the brand's sustainability initiatives, ethical standards, and quality requirements.
- Make use of data analytics to gain customer understanding gain insight into consumer preferences and behavior patterns by using customer data, which can help marketing and loyalty programs work better. Work together with brand ambassadors and influencers.
- Involve devoted consumers and local influencers to spread the word about the company in a genuine way.
- Constantly innovate Introduce limited editions or new products on a regular basis to maintain consumer interest and promote trial without offending devoted patrons.

- Preserve the resilience of the supply chain make sure your inventory and sourcing are trustworthy to prevent interruptions that can lower client satisfaction.

Further Scope for Research and Discussion

Future research on how tools like artificial intelligence, mobile apps, and social media platforms affect customer loyalty in the food and beverage business is made possible by the rapid progress of digital technologies. Businesses can create more successful engagement strategies by comprehending how engaging digital experiences, streamlined online ordering, and targeted marketing increase customer loyalty. Furthermore, as more consumers give health, environmental responsibility, and transparency top priority when making purchases, it is imperative to look into how sustainability initiatives and ethical consumerism affect loyalty. Research on these topics may uncover new factors that influence loyalty and offer guidance on how companies can better match their beliefs with those of their target audience.

Comparative studies that look at loyalty across several industry segments—like cafes, restaurants, and packaged food brands—as well as across various demographic and cultural groups are also needed. This would provide insight into the particular difficulties and inclinations that affect loyalty behavior in diverse settings. Examining the psychological and emotional aspects of loyalty, such as the significance of identity, trust, and nostalgia, may enhance comprehension beyond transactional exchanges. Additionally, examining how social media and economic shifts affect consumer loyalty recovery and retention would give them the tools they need to sustain solid client connections in a market that is constantly shifting.

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INDOLE ACETIC ACID (IAA) AND ITS GROWTH MULTIPLICATION PARAMETERS IN THE CONTROL OF SOIL ORGANIC POLLUTION

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ABSTRACT

Enhancing the growth of tobacco (*Nicotiana tabacum*) seedlings by Indole Acetic Acid (IAA) hormone was the reason behind this study. Seedlings of *N. tabacum* treated with equal quantities of IAA hormone (0.7%) were grown in 1kgs of vermuculate, perlite, planting soil, sand, and equal mixture of all media. The set up were treated equally with water and organic manure. Control set up was made with a mixture of different rooting media without IAA. Data on shoot development were noted for 6 weeks and root length was measured on the day of harvest. The parameters measured were analysed statistically using ANOVA, and it was found out that root and shoot lengths were significant at $p>0.05$ in the entire rooting media and the highest percentage development (49 and 51%) respectively for root and stem respectively, was observed in the rooting media that has equal measure of each constituent (i.e. the mixed constituents). Germination rate among the media were 100, 70, 60, 50 and 40% for mixed, sand, planting soil and vermiculate, perlite and control respectively. Different sections of mature stem tested with IAA hormone were not significant in their root and stem development, although basal cutting stems tend to mature faster than epical. This therefore means that propagating *N. tabacum* by seedlings can be optimally achieved through mixture of 0.7% of IAA in a collection of different rooting media.

Keywords: *Nicotiana tabacum, Indole Acetic acid, Root formation, Rooting media, Growth enhancement*

1.0 Introduction

Tobacco is an important commercial and agricultural plants growth in several part of the globe because of its economic need. This is a plant with a common name of several plants in the genus *Nicotiana* of the family *Solanaceae*, and the general term for any product prepared from the cured leaves of these plants. More than 70 species of tobacco are known, but the chief commercial crop is Nicotiana tabacum. (Singh *et al.* 2009). Tobacco is a plant (Nicotiana tabacum and Nicotiana rustica) that contains nicotine, an addictive drug with both stimulant and depressant effects. Tobacco leaves are used to make products that can be consumed in different ways: smoked in cigarettes, cigars or pipes. smoked in loose form in hookahs. All forms of tobacco are harmful, and there is no safe level of exposure to tobacco. Cigarette smoking is the most common form of tobacco use and the reason is because it contains nicotine because of the highly addictive stimulant alkaloid nicotine as well as harmala alkaloids. Tobacco use is a cause or risk factor for many deadly diseases, hence is always advised that tobacco smoking is dangerous to health.

Indole acetic acid (IAA) is the main auxin in plants, regulating growth and developmental processes such as cell division and elongation, tissue differentiation, apical dominance, and responses to light, gravity, and pathogens. IAA stimulates overproduction of root hairs and lateral roots in plants and release of saccharides from plant cell walls during the elongation (Sosnowski *et al*. 2023). Saccharides are a source of nutrients for microorganisms and can increase the colonization ability of plant-associated bacteria, this is because IAA production is a major property of rhizosphere bacteria that stimulate and facilitate plant growth. Indoleacetic acid (IAA) is a molecule that is synthesized by plants and a few microbes (Ansari *et al.* 2023). In plants, IAA plays a key role in both root and shoot development. The hormone moves from one part of the plant to another by a designated importer (AUX1) and efflux pumps (PIN1–7). IAA also regulates geotropism by accumulating on the underside of shoots and roots. In shoots, IAA causes cell elongation on the underside of the shoot, causing it to bend upwards, away from the force of gravity. In roots, IAA inhibits cell growth, causing roots to grow downwards, towards the force of gravity.

The medicinal properties of plants lie in their phytochemical components like alkaloids, flavonoids, tannins in addition to other phenolics that co-opt as to producing definite physiological functions to the body of man and animals (Taiwo et al. 2000; Che Man 2010). However, analysis of extracts of *N. tabaccum* were found to be rich in flavonoid and flavonones, triterpene, terpenic compounds, chalcone, steroids as well as peroxidise isoenzymes (Anup et al. 2011; Anyasi *et al*. 2019; Raymond Anyasi and Anyasi, 2020). It is also rich in carbohydrates, high content of total proteins in addition to high percentage of nitrogen. All these contribute to the high phytochemical properties of the plant. *N. tabacum* is therefore grown as a medicinal plant for the treatment of skin wounds especially in Indonesia (Metwally and Ekejuba 1981; Phan et al. 1996). In South Africa for example, the leaf of *N. tabacum* is used for the production of tobacco by the tobacco companies. However, because everyone deserves a fair and just opportunity to be as healthy as possible, this is known as health equity. Therefore, achieving health equity means addressing system-wide problems, unfair practices, and unjust conditions that have a negative impact on the health of specific groups. To achieve health equity, it is important to eliminate health disparities which are differences in health outcomes that are closely linked with social, economic, and/or environmental factors, that affect the entire people of the globe (Taiwo et al, 2000). To improve health equity, we must consider the role of commercial tobacco (Phan et al. 1996; Akinmoladun et al., 2007; Anup et al., 2011).

N. tobacum has also been implicated by its diuretic, hepatotropic and astringent properties (Weninger and Robenean 1988; Iwu 1993).

N. tobacco can be propagated mainly by seeds, this is one of the significant agronomic properties of the plant (Tanhan *et al*., 2007; Anyasi *et al*. 2019). However, it has been reported that germination of seeds from weeds are most likely affected by soil compositions especially in the field study, therefore such propagation is aided by agronomic factors that enhances the growth and multiplication of such plant (Adebayo *et al*., 2005; Agbo and Obi 2007). Moreover, as some other types of propagation such as stem cuttings propagation prolongs hybridization of genome as segregation through recombinant gene is avoided, this may not be possible in some plants for example in the tobacco plant we are studying.

The success of rooting has been attributed amongst other factors to the rooting medium as well as the presence of rooting hormone and its concentration (Al-Saqri and Alderson 1996; Hartmann *et al*. 1997). Influences of rooting media and hormone on rooting in different kinds of plant have been documented and its effects in structure propagations were elucidated (Akwatulira *et al.* 2011). These media combination used in the rooting of the seedlings provide physical support as well as oxygen and water to the plant seeds (Larsen and Guse 1997). However, IAA; an auxin containing product was reported to stimulate adventitious roots in of some plants (Araya *et al*. 2007). This was buttressed by the study by Rao *et al*. (2005) which reported that IAA was the leading plants hormone used to promote the formation of roots in Tomatoes. Hence with the quest for a systematic search for specific useful factors from plants like *N. tobacum*, even though most plants can root without hormone, there is need for an improved method of propagation and growth for such nutraceutical plants. This will therefore form a rational approach towards drug and nutritional research. The aim of this study was to evaluate the effect of IAA hormone and rooting media for optimal rooting of propagated *N. tabacum*.

2.0 Materials and methods

Seeds of *N. tobacco* plants was collected from the greenhouse at the University of South Africa in Pretoria (25º46’1”S, 28º12’2”E) and 1439m above sea level. The experiment took place in polyvinyl chloride (PVC) pots with dimensions 30x25x30 at a garden at the University of South Africa at Florida Campus. The pots contain 1kgs of different rooting medium that has been mixed with equal volume of organic manure collected at the animal farm of the University of Pretoria in Onderstepoort. Inside each pot was made holes designed to contain equal weight of IAA hormone (0.7%), for the plants. The set up was made in a complete randomized design containing a 3x4 factorial treatment model (Jeruto *et al*. 2008). The rooting media used here were planting soil and humus in the ration of 2:1 (w/w). About thirty-six plantlets were used in each set of rooting media and IAA hormone concentration by volume percentage. Then sets of water treated seedlings were sawn into holes containing the IAA hormone in the rooting media and were replicated by three. Random allocation of plant seedlings to the rooting media using random digit from a table was employed as to eliminate bias (Johnson and Bhattacharyya 2006).

2.1 Rooting media

The rooting media was homogenized by hand, mixed with equal volume of organic manure and air dried on an impervious polythene sheet for 24 hours, there were pasteurized and fumigated, measured into the PVC pots with the hole containing about 0.7% of IAA hormone. This concentration was chosen because of its optimum performance from other unpublished trials.

2.2 Propagation of the seedlings

The 10.0 cm Plantlets with lateral buds were about 360 collected at tale end of the afternoon when the weather was moist and were kept in a bow containing water (Agbo and Obi 2007). The bases were made squared using sharp sickle to spread the rooting. For each of the cuttings, about half of it was dipped into the IAA hormone that has been made into hole in each of the pots as to soak the powder. Excess of it was shaken off the base of the cuttings and the hormone was manually made to concentrate at the base. The plantlets were then inserted into the soil to about 6 cm, watered and maintained to about 70% humidity (Tanhan *et al.* 2007). Fungicides were sprayed onto the plants to control infections (Yeboah and Amoah 2009). The set up was allowed to grow for six weeks while monitoring in between days to remove any invading weeds. Data on shoot development was taken at interval of weeks and root length was measured on the day of harvest after weeks.

2.3 Data collection

Data collection which commenced on the first week after propagation continued till the sixth week and the parameters measured were survived seedlings, length of shootings/buds, and the root length, number, and weight of the plant on the day of harvest.

2.4 Data analysis

The data collected was analysed using Microsoft excel to obtain the mean number and percentage of plants that were able to form developed root and sprouted shoots from the series of transplanted seedlings. The data was then imported into SPSS version 13.0 and was analysed using analysis of variance (ANOVA) and standard deviation for the length of shoot and roots. The significance effects were determined at 5% level of significance.

3.0 Results

N. tabacum seedlings treated with concentration of 0.7% (w/w) IAA hormone propagated in different growth media recorded the highest mean number of the seedlings that developed roots and sprouted shoots in the set up with equal mixtures of the 4 growth media with organic manure. While the stem seedlings propagated in the perlite and control recorded the least mean rooted (2 each) and sprouted shoots (4 and 3) as recorded in Table 3.1. Amazingly, perlite and vermiculate maintained almost equal numbers of shoot developed (4 and 3 respectively) like in the root (2 each). However, significant difference existed among the different media with reference to their mean rate of development and formation of root and shoot. The efficacy of IAA hormone to the development of root and shoots was noticed by the difference between the treated samples and the controls without the hormone. There was significance difference between the two samples.

Number and length of roots developed among different rooting medium and the concentration of hormone were not significant (Table 1.0) but shoot lengths and number per sprouted stem was significant. Increase in shoot length occurred in this order: mixture>vermiculate>perlite>planting soil>sand>control while increase in root length were in the order: mixture>vermiculate>perlite>planting soil>sand>control. But it made a turnaround in the number that rooted and shooted within the rooting media, i.e., sand and planting soil had the same mean number of roots (4) and a little difference in Shoots (6 and 12). The control media maintained equal numbers. In fresh weight of the plants (apical and basal), there were higher weight measurement in the basal sections than the apical ones, though not significant. Equally, set up containing the mixture of the rooting media still maintained the highest weight followed by sand, perlite, planting soil, vermiculate and the control. The same sequence was

also followed in their dry weights. In sand however, there were greater number of root numbers while in other rooting media had the same number of roots. Shoot and root length of mixture of rooting media and vermiculate were synonymous with each other and were almost significant with the rest of the medium. Root lengths were 34 and 33mm for mixture and vermiculate respectively, 39 and 37mm in sand and planting soil. The shoot length was 41mm in both sand and vermiculate, while 43mm all in planting soil and mixture respectively. The set up containing equal mixtures of all media had 100% germination rate compared to 70, 60 50 and 40% for sand; planting soil/vermiculate; perlite and control respectively. However, the rest of the media demonstrated improved significant effects in all the parameters measures compared to the control.

Discussion

The rooting medium supplement that has mixtures of planting soil, perlite, sand and vermiculate at equal proportion enabled highest development of root and shoot in a cutting of *N. tabacum*. This improved effect could be attributed to the fact that the combined nutrient supplement of the entire rooting media acted optimally with the IAA hormone concentration added which created the enabling soil condition for example, optimum aeration and moisture level (Kalyoncu and Ozer 2000; Akwatulira *et al.* 2011). Meanwhile dose application of IAA hormone was shown to be an aid to improved moisture content in the soil for an optimal rooting and shooting development of cuttings (Milleton *et al*. 1980; Leakey *et al*., 1982; Aminah et al. 2006; Akwatulira *et al.* 2011; Raymond Anyasi and Anyasi 2020). However, most of these past studies maintained their IBA hormone concentration to about 0.7-0.8% of the rooting media used while this study based its IAA measurement on the weight of the cuttings. Morever, the control sample of rooting medium supported low development of root and shoot than the auxin treated samples in the entire experiment. This could perhaps be becouse soil resistant to root penetration is dependent on amongst other factors on water content, structure and strength of soil as well as bulk densities though these were not measured in the rooting media (Amri *et al*. 2009). Soils do not posses the required aeration porosity for optimal gas exchange required for rooting of the cuttings resulting in poor rooting in the control. Poor rooting numbers in control could also be attributed to the feel of anoxia which is an effect of low oxygen in the soil (Hartmann *et al*. 2002). Low incidence of rooting was found in the control samples. Non-theless, there are instances where optimum concentration of IAA in the soil has resulted in the failure of the development of roots by stem cuttings as was reported by Griffin and Shroeder (2004). That was an indication of the sensitivity of root formations to hormone formulations (Akwatulira *et al.* 2011; Anyasi 2023). It has also been reported that rooting hormone to a certain instance could be inhibitory to the development of roots in the cutting especially during the initiation stage (Akwatulira *et al*. 2011). This then means that different rooting media accommodates different concentration of auxin for optimal growth of plants.

Conclusions

Mixture of various rooting media in the right proportion with 0.7% of IAA hormone has been proven to be effective in the root and shoot development of cuttings of tobacco irrespective of the position of the cuttings. Although the individual medium did not have high incidences in most of the parameters measured, but there were able to support root and shoot development as well. Therefore, there is need for a study of IAA concentration effects on the media as to be able to determine if concentration was not the factor responsible for the low root and shoot development. This will promote mass production of *N. tabacum* especially in areas that the plants do not occur naturally.

Acknowledgements

Wish to express my appreciation to the University of South Africa and National Research Foundation for their assistance in this project.

Tables and Figures

Table 1.0 Number of rooted and shooted seedlings within rooting media. Values are mean of replicates (Numbers with same superscript within same row are not statistically significant at p=0.05)

Rooting media	Number of cuttings		IAA hormone concentration
	Rooted	Shooted	
Planting soil	4±0.75[a]	12±2.55[b]	0.7
Control	2±0.69[a]	3±0.00[a]	0.7

Table 2.0 Rate of germination of shoots among rooting media with 0.7% concentration of IAA hormone. Values are mean of replicates (Numbers with same superscript within same row are not statistically significant at p=0.05)

Rooting media	IAA hormone concentration (%)	Rate of germination (%)
Planting soil	0.[7a]	60[b]
Control	0.7[a]	40[a]

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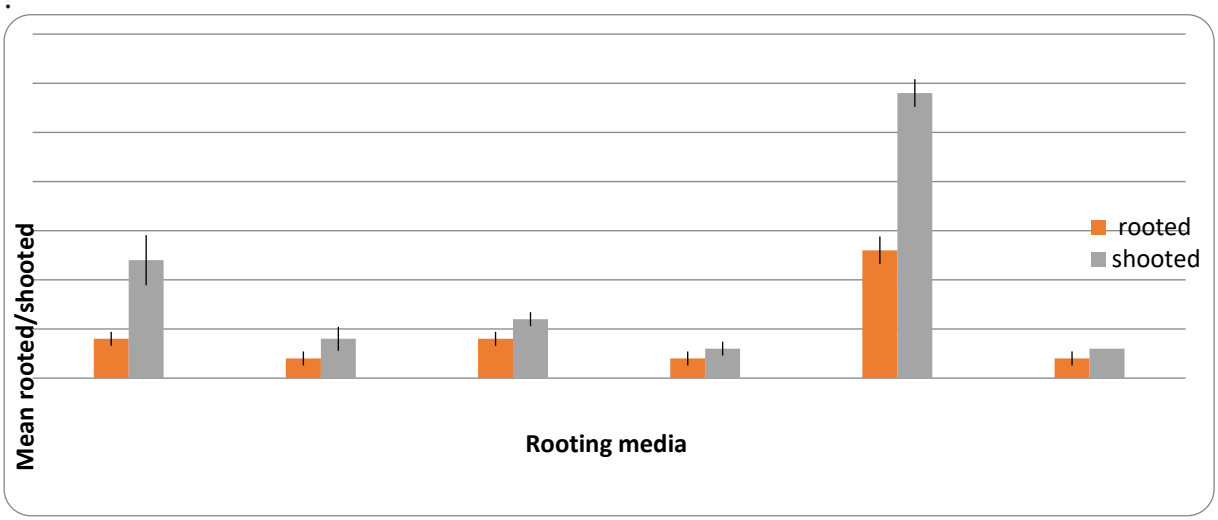


Figure 1.0 Bar chart representation of the means values of rooted and shooted seedlings within rooting media (The error bars represent the standard error from the mean).

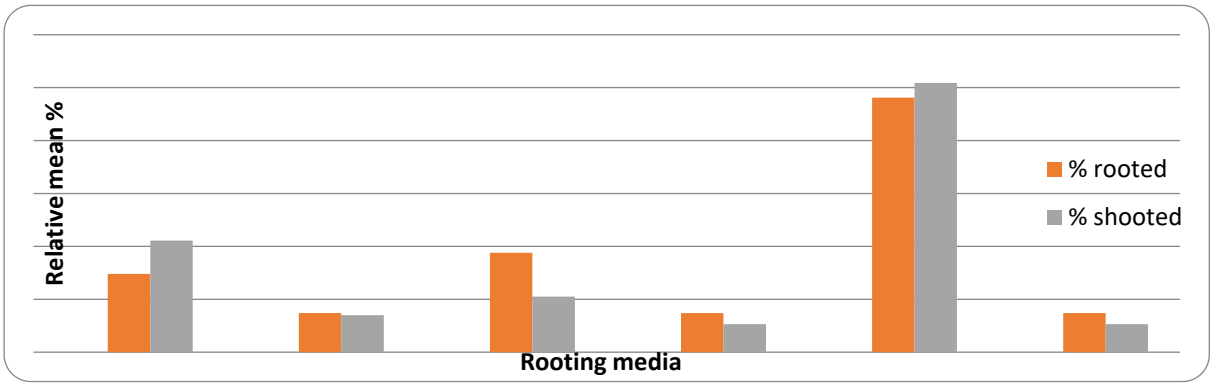


Figure 2.0 Relative mean percentage of the rooted and shooted seedlings among the rooting media.

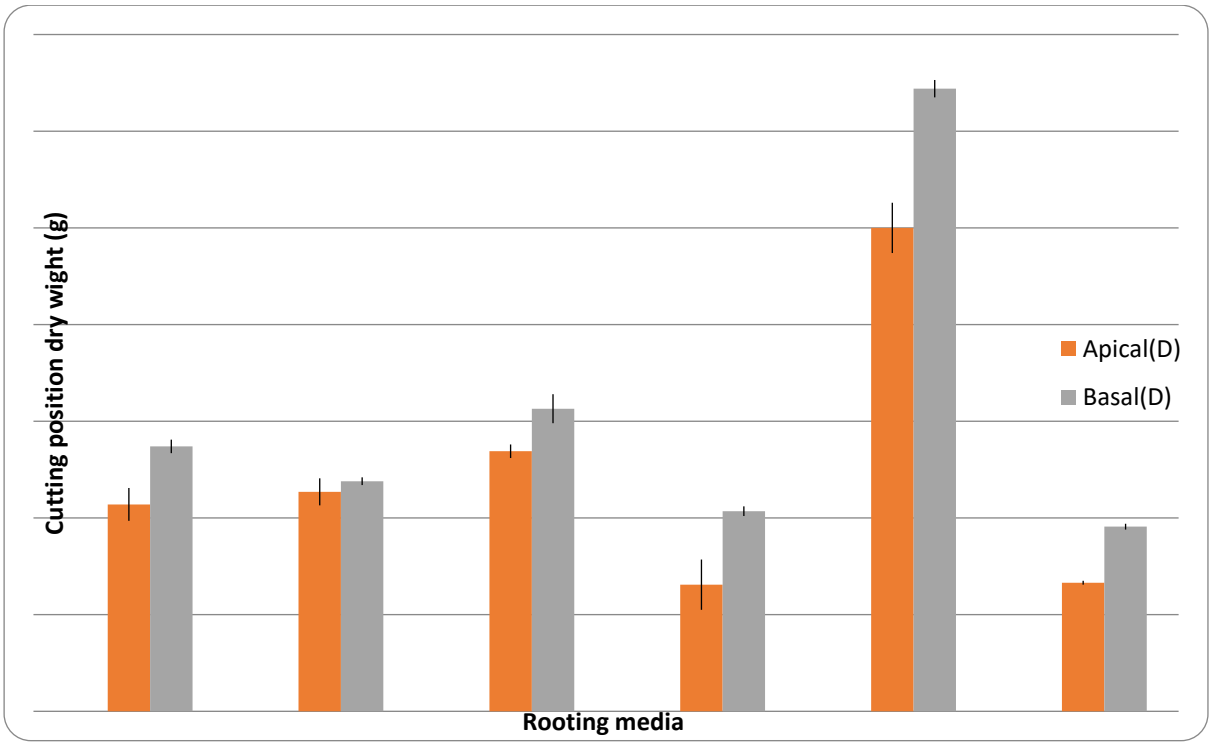


Figure 3.0 Dry weight of Cutting positions within different rooting media (The error bars represent the standard error from the mean)

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THE MACHINING PARAMETERS AND APPLICATION AREAS OF LASER BEAM CUTTING (LBC) METHOD

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ABSTRACT

Laser beam cutting (LBC) or in other words laser cutting, which is widely used in metal sheet forming and material processing fields today, is increasing gaining popularity due to the advantages of its offers in terms of precision, speed and efficiency. In LBC, various cutting techniques are used depending on material properties, employing different types of lasers such as carbon dioxide (CO_2), neodymium doped yttrium aluminium garnet (NdYAG) and fiber lasers. The LBC is not limited to cutting operations only, but also has many different application areas such as marking, engraving, hole drilling and welding. Among LBC machine structures, flying optics and moving table systems are widely preferred, as they directly influence cutting performance and quality. While the high precision and flexibility it provides make the LBC method attractive for many industrial applications, factors such as the high investment cost of LBC machines and post-cutting thermal effects on workpieces also pose disadvantages for the LBC. In this study, the fundamental principles, application areas, machine structures and machining parameters of the LBC method are comprehensively explained based on scientific studies in the literature. The effects of machining parameters such as laser power, cutting speed, focus position, pulse frequency, nozzle tip distance, assist gas type and pressure on cutting qualities such as kerf width, kerf taper, dimension tolerances and surface roughness are explained in detail. In addition, the general structure and machining parameters of LBC technology were evaluated from a holistic perspective and its contributions to the manufacturing industry were discussed.

Keywords: Laser beam cutting, CO_2 laser, NdYAG laser, fiber laser, laser power, cutting speed.

1. Introduction

The LBC method is widely used in many sectors such as automotive, medical treatment, scientific research, aerospace and electronics, especially in the defense industry, thanks to its high precision, accuracy, non-contact cutting and fast production advantages (Tamilarasan & Rajamani, 2025; Zhang et al., 2024). Especially in the production of parts with complex geometries, the processing flexibility and minimum material loss offered by LBC have made LBC an indispensable manufacturing method among today's sheet metal forming methods. (Tamilarasan & Rajamani, 2025). LBC is not limited to cutting, but also includes other applications such as marking, engraving, drilling and welding. In terms of machining physics, LBC is a thermal process. First, the laser beam is generated using various laser beam generation sources such as carbon dioxide (CO_2), NdYAG or fiber lasers. The resulting laser beam is focused on the material to be cut and melting or vaporization occurs where it hits. This is how the cutting process takes place. Using different types of laser beams, it is possible to process a wide variety of surfaces such as metal, plastic, ceramic, wood and composite materials (Köle, Ayan, & Kahraman, 2024). Although research on laser material processing has been conducted since the mid-20th century, the first working laser system was developed by Theodore Maiman in 1960. Maiman used a ruby crystal to power this first laser, laying the foundation for modern laser technology and paving the way for today's advanced laser systems. (Ryan, Spetzler, & Preul, 2009).

In the literature, there are many experimental studies investigating the effects of the processing parameters of the LBC method on the output performance. For example; Yilbas et al (Yilbas et al., 2010) performed LBC process by reinforcing AA7050 aluminium alloy with 20% Al_2O_3 and B_4C. They prepared the composite materials produced by powder metallurgy method as 3 mm thick sheets. They performed the cutting processes using a CO_2 laser and used nitrogen as an auxiliary gas. In LBC, they determined the laser power in the range of 2500-3500 W, pulse frequency in the range of 500-1500 Hz, nozzle aperture of 1 mm and gas pressure of 450 kPa. They evaluated the cutting quality outputs such as kerf width, planarity, waviness and microstructure properties through scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS). From the result of their experimental studies, they obtained wider and irregular cutting surfaces in Al_2O_3 reinforced composites, while they obtained smoother surfaces and constant kerf widths in B_4C reinforced composites. They attributed this to the high thermal conductivity and structural stability of B_4C. They also observed that the kerf width increased significantly with increasing laser power and the cutting quality deteriorated. Patel et al (Patel & Sanghavi, 2014) investigated the effects of processing parameters on cutting quality in cutting processes on AISI304 stainless steel using a CO_2 laser cutting machine (Mazak Hyper Gear 510). In their experimental studies, they evaluated three basic cutting parameters, namely laser power (1300-1500-1700 W), auxiliary gas pressure (2000-2100-2200 bar) and feed rate (0.5-0.6-0.7 mm/s) with Taguchi L27 experimental design. They performed 27 experiments in total by applying each parameter at three different levels. They evaluated the output performance by determining the upper-lower kerf width, kerf taper angle (taper) and the average surface roughness (Ra) values obtained after cutting. From the experimental results analysed by the analysis of variables (ANOVA) method, they determined that the parameter that most affected the surface roughness was laser power with a contribution rate of 55.89%. They determined the effect of gas pressure as 12.27%, while the contribution of feed rate (0.06%) was found to be very low. They concluded that in order to obtain optimum surface quality in laser cutting processes, especially the laser power parameter should be carefully selected.

Lee et al (Lee & Choi, 2020) investigated the effects of different processing parameters (laser power, cutting speed and oxygen gas pressure) on the cutting quality of 22MnB5 boron steel sheets in CO_2 LBC technology. Laser power: 150-225-300 W and cutting speeds: 150-200-250 cm/min. Using oxygen as an auxiliary gas, they set the pressure levels as 2 bar, 3 bar and 4 bar. According to the results of their experimental studies, they observed that the increase in laser power improved the cut edge quality. On the other hand, they discovered that higher laser power produces a wider heat affected zone (HAZ). As the cutting speed increased, they observed a decrease in the width of the HAZ, which positively affected the cutting quality. They also observed that increasing the oxygen gas pressure has an improving effect on surface roughness. The best machining parameters: 173 W laser power, 204 cm/min cutting speed and 4 bar oxygen pressure. They obtained a steepness tolerance of 18.7 µm, a surface roughness of Ra = 20.8 µm, an upper cutting width of 179 µm and a HAZ width of 69.2 µm.

Yadava et al (Yadava & Kumar, 2013) investigated the machinability of aluminium metal matrix composite (MMC) materials, known for their challenging machinability properties, in the LBC method. In particular, they determined the optimal processing parameters for CO_2 laser cutting of SiC reinforced Al composites. From the results of their experiments, they observed that the workpiece removable rate (WRR) increased with increasing laser power and cutting speed, but the kerf width and surface roughness value also increased. They also found that the HAZ width and edge quality were negatively affected as the SiC reinforcement ratio in the Al composite content increased. They explained that this is due to the high thermal conductivity and reflectivity of the SiC particles, which makes effective absorption of laser energy difficult. They determined the best processing parameters as: moderate laser power (750 W), moderate cutting speed (10 mm/s) and low SiC reinforcement ratio (10%). They also reported that careful selection of the processing parameters has a decisive influence on the cutting quality and the reinforcement ratio directly affects the machinability in the LBC process of MMC materials.

Rao et al (Rao et al., 2005) investigated the cutting of titanium sheets in an inert gas environment with a CO_2 laser operating in pulsed mode using different processing parameters. In their experimental studies, they used commercial purity titanium sheets with a wall thickness of 1 mm and cut them with a maximum laser power of 400 W. During the cutting processes, they varied the laser power (200-400 W), pulse frequency (10-50 Hz), cutting speed (50-150 mm/min), gas pressure (0.5-1.5 MPa) and determined the effects of argon (Ar) and nitrogen (N_2) gases on cutting. They used L9 orthogonal array based on Taguchi method and determined 9 different experimental conditions. With other processing parameters constant, they found that the cutting width was approximately 2.8 mm, the surface roughness Ra = 3.0 µm and the HAZ width was 0.5 mm with 400 W laser power. With 200 W laser power, they determined the cutting width as 1.5 mm, surface roughness Ra = 1.8 µm and HAZ width as 0.3 mm. When they used a low pulse frequency (10 Hz), they stated that the cutting surface improved (Ra = 1.5 µm) and the HAZ width narrowed. When they used a high pulse frequency (50 Hz), they found that the surface roughness increased (Ra = 3.2 µm). They determined the kerf width as 1.2 mm at low cutting speed (50 mm/minute) and 2.5 mm at high cutting speed (150 mm/minute). At 1.5 MPa gas pressure, they measured the slag height as 0.3 mm. When they used low gas pressure (0.5 MPa), they measured the slag at lower levels (about 0.2 mm) and stated that the cutting surface was smoother. They measured the slag height as 0.2 mm, HAZ width as 0.4 mm and surface roughness as Ra = 1.5 µm using argon gas. In their experiments with nitrogen gas, they determined the slag height as 0.3 mm, HAZ width as 0.6 mm and surface roughness as Ra = 2.5 µm. They obtained the best cutting quality by using low pulse frequency (10 Hz), low cutting speed (50 mm/min) and argon gas. Using this combination, they were able to minimize

the cutting surface roughness Ra = 1.5 µm, the cutting width 1.5 mm and the slag height 0.2 mm.

Buj-Corral et al (Buj-Corral, Costa-Herrero, & Domínguez-Fernández, 2021) investigated in detail the effects of pulse frequency, pulse width and cutting speed on surface quality in NdYAG laser cutting of 0.8 mm thick AISI304 stainless steel plates. They evaluated a total of 8 experimental conditions with 2^3 full factorial experimental design. They determined the surface roughness, dimensional error rates (Ra) and burr thicknesses in the experiments and determined the effective parameters on these outputs by regression analysis. They found that the surface roughness was most affected by the pulse frequency (adj. R^2 = 78.32%), followed by the pulse width. They observed that the lowest Ra value (1.89 µm) occurred at the combination of low frequency (50 Hz) and low pulse width (0.4 ms). They stated that the most effective parameter in terms of dimensional error was pulse width (adj. R^2 = 84.47%). The lowest dimensional error rate (0.22%) was obtained at high pulse width (0.6 ms) and high cutting speed (140 mm/min). They found that the burr thickness was most affected by the pulse frequency (adj. R^2 = 88.35%). From the multi-objective optimization analyses, they stated that the most suitable machining parameters they recommended to improve the quality criteria simultaneously were high frequency (80 Hz), high pulse width (0.6 ms) and high cutting speed (140 mm/min). Riveiro et al (Riveiro et al., 2017) investigated the effects of different gas supply systems and auxiliary gases (argon, nitrogen, oxygen, air) on cutting performance and surface chemistry in CO_2 laser cutting of Al-2024-T3 aluminium-copper alloy. They cut 3 mm thick sheets with a 3.5 kW CO_2 laser operating in TEM_{00} mode. They characterized the cut surfaces by optical microscopy, SEM, X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) analysis. They found that the supersonic gas supply system achieved higher cutting speeds (e.g. ~10,000 mm/min at 3000 W laser power) and better surface roughness (Ra = 1.8 µm) than the subsonic system. With argon gas, they obtained the highest cutting speeds (10,000 mm/min) and the lowest roughness value (Ra = 3.7 µm). In terms of kerf width, they made the narrowest cut (0.27 mm) with Argon. The widest cut (0.40 mm) was made with oxygen. From XPS analysis, they discovered that oxide and nitride formations were minimized by using Argon.

Madić et al (Madić et al., 2020) developed a multi-criteria optimization model aiming to increase the IHV during CO_2 laser cutting of 2 mm thick mild steel (S235JRG2) material. In their study, they created empirical models including criteria such as burr formation, kerf width, steepness tolerance, gas pressure, surface roughness and cutting energy. They performed the optimization process with an exhaustive iterative search algorithm. They determined the optimal machining parameters as: v = 5.89 m/min, P = 1.18 kW and p = 3.01 bar. With these parameters, they obtained an HRV value of 2944 mm^3/min. Hajdarevic et al (Begic-Hajdarevic & Bijelonja, 2022) investigated the CO_2 laser machinability of an alloy containing 93% tungsten, which is difficult to be laser machined due to its high melting temperature (3100 °C) and high density (17,600 kg/m^3), by experimental and numerical methods. In their experimental studies, they used 974 W real laser power with 6 bar nitrogen as an auxiliary gas, the focal radius was 0.105 mm and the drilling time was 8×10^{-3} s. They defined the properties of the material such as latent heat (250 kJ/kg), absorption coefficient (0.86) and heat transfer coefficient (25 W/m^2-K) in their model. From the experimental results, they found that the hole entrance diameter was 60% larger than the exit diameter in 1 mm thick specimens, while this ratio was 32% for 0.5 mm plate. Using microstructure analysis, they reported that the binder phase evaporated and filled the grain boundaries and microcracks formed in some areas. They stated that the HAZ dimensions and hole geometries obtained from numerical modeling showed high agreement with the experimental results.

M.A. Elbah et al (Elbah et al., 2015) experimentally and statistically investigated the CO_2 laser cutting process of 3 mm thick polycarbonate (PC) sheets. They used Response Surface Methodology (RSM) for process optimization and applied Central Composite Design (CCD) as experimental design. They used a CO_2 laser system in continuous wave (CW) mode with a wavelength of 10.6 μm and a 127 mm focal length lens to perform cutting operations on the top surface of the workpiece. In their experimental studies, they used different combinations of laser power (160-200 W), cutting speed (300-500 mm/min) and focal position (-2, 0, +2 mm). They determined the kerf width, Ra value and HAZ area by using optical microscope and surface profilometer measurement devices. They evaluated the suitability of their model and the effects of machining parameters by subjecting their result data to ANOVA analysis. They found that increasing the laser power increased the kerf width and HAZ area but had little effect on the surface roughness. On the other hand, increasing the cutting speed decreased the kerf width and HAZ area, but caused a significant increase in surface roughness. In terms of focus position, the best results were obtained when focusing on the surface of the workpiece (f = 0 mm). They also observed that the interaction of laser power and cutting speed has significant effects on kerf width. As a result of their optimization, they obtained minimum kerf width (~0.48 mm), minimum surface roughness (Ra =2.3 μm) and minimum HAZ width (~0.88 mm^2) values under conditions where the laser power was 180 W, the cutting speed was 400 mm/min and the focus position was 0 mm. They concluded that careful selection of processing parameters in CO_2 laser cutting of polycarbonate materials can improve both cutting efficiency and quality.

Ghany et al (Abdel Ghany & Newishy, 2005) comparatively investigated the use of pulsed and continuous wave (CW) NdYAG lasers in the LBC method in terms of cutting performance of 1.2 mm thick austenitic stainless steel plates. They used nitrogen (N_2) as an auxiliary gas in their studies. In their experiments in pulsed mode, they adjusted the average laser power in the range of 300-500 W, pulse duration between 0.5-1.2 ms and frequency between 150-500 Hz. In CW mode, they selected the laser power in the range of 500-1200 W. They varied the cutting speed between 0.5-3.0 mm/s for both modes. They tested the focal spot position between -2 mm and +2 mm to obtain the best cutting conditions. They found that the cutting of 1.2 mm thick stainless steel using the pulsed mode was only possible at an average laser power of 500 W and a frequency of 500 Hz, at lower values the material could not be cut completely. They obtained the best cutting quality in pulsed mode at a focal position of -1 mm and a cutting speed of 1.5 mm/s. They observed burr-free and smooth cutting surfaces under these conditions. In CW mode, they were able to obtain faster and continuous cuts in the 900-1100 W laser power range and 2.0-2.5 mm/s cutting speed range. However, they observed a wider HAZ around the cutting edges when cutting in CW mode. They explained that HAZ widths increased in CW mode because more energy is transferred by thermal diffusion due to continuous energy input to the workpieces. They stated that shifting the focal plane up or down relative to the material surface directly affects both cutting quality and burr formation. In CW mode, they found that when the focal point is 1 mm below the surface (-1 mm), the cutting surface is smoother and burr formation is minimized. They stated that pulsed laser is suitable for more precise and burr-free cutting, but the process time is long and energy consumption is high. In contrast, they found that the CW mode, although it allows machining at higher cutting speeds, has some disadvantages in terms of surface quality. They concluded that the correct choice of LBC processing parameters and operating mode plays a critical role in laser processing of highly reflective and thermally conductive materials such as austenitic stainless steel.

Riveiro et al (Riveiro et al., 2008) investigated the technical challenges in CO_2 laser cutting of AA2024-T3 aluminium alloy, which is widely used in the aerospace industry, and a novel

approach to overcome these challenges. In their study, they pointed out the material's properties, such as high laser reflectivity and high thermal conductivity, which make laser processing difficult. To overcome these challenges, they designed a new laser cutting head with an auxiliary gas jet operating in the supersonic regime and compared its performance with a conventional coaxial cutting head. From their findings, they found that the cuts they made using the supersonic cutting head had smoother surfaces free of burrs and cracks. While they obtained significant burr formation and higher surface roughness (Ra > 6.00 μm) with conventional machining, they observed that this value decreased to 2.70 μm with the supersonic head. They also found that the HAZ width was significantly reduced with the supersonic cutting head.

In this study, a comprehensive literature review on the LBC method has been conducted and the technical foundations of the method, the types of lasers used, machine structures, machining parameters and application areas have been explained in detail. In addition, information on the advantages-disadvantages and limitations of LBC is also given.

2. Laser Beam Cutting (LBC) Method

LBC is a non-contact and precise manufacturing method in which a beam of light with intense energy is focused on the material and heat-induced cutting is performed (Powell & Kaplan, 2004). In the LBC method, a high intensity laser beam is obtained through a power source (Figure 1).



Figure 1. The processing moment of the LBC method (Unclazer.com, n.d.)

As shown in Figure 2, a control unit on the LBC machine allows the cutter head of the LBC machine to move. With this movement, the laser beam comes to the area to be cut and high temperatures are obtained on the cutting surface by focusing the laser beam by the cutter head, whose schematic cross-sectional view is shown in Figure 3. In this way, melting and vaporization is achieved on the material surface. An auxiliary gas used during cutting removes the molten and vaporized materials in the cutting area. Thus, the cutting process is realized on the material.



Figure 2. Control unit on the LBC bench (Hsglaser.com, n.d.)

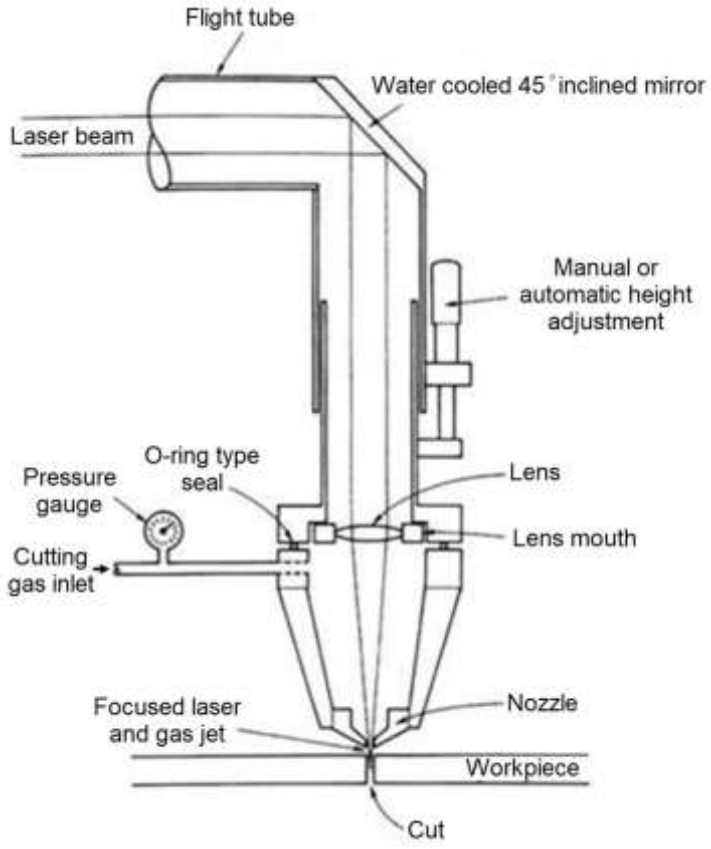


Figure 3. The schematic section view of the cutter head of LBC machine (Powell & Kaplan, 2004)

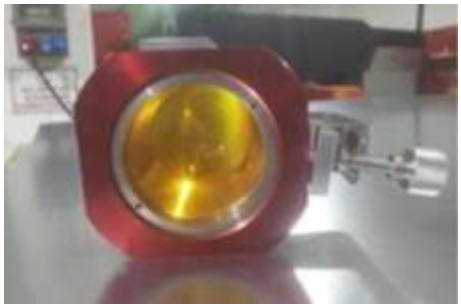


Figure 4. Laser lens (Tunç, 2015)



Figure 5. Nozzle example on LBC machine heads (Tunç, 2015)

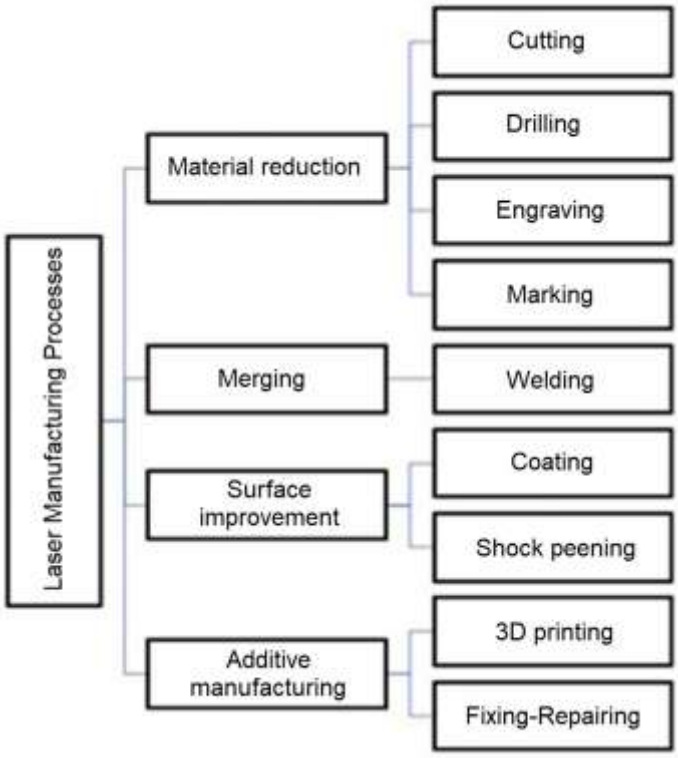


Figure 6. Manufacturing processes using laser beam (Köle, Ayan, & Kahraman, 2024)

While LBC is being made, there is loss of material along the cutting line due to melting and vaporization of the material and a cutting gap (kerf) is formed as seen in Figure 7.

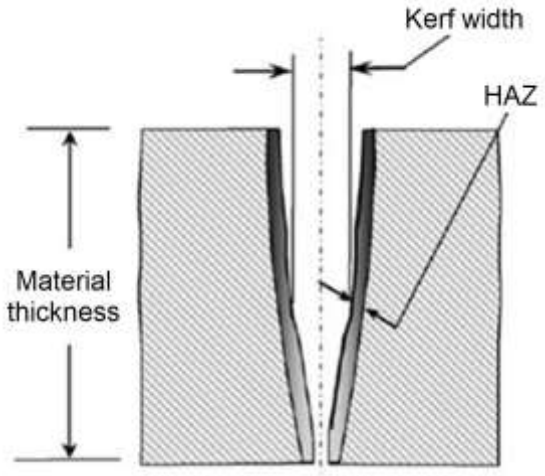


Figure 7. Kerf formed on the material as a result of the LBC process (Stournaras et al., 2009)

2.1. LBC method types

2.1.1. CO_2 laser cutting

CO_2 lasers (10.6 m wavelength) have approximately 30% higher efficiency, higher beam quality (close to optimum Gaussian mode (Bass, 1983)), greater focal depth, smaller beam diameter. Using a 2000W continuous laser beam, 16 mm mild steel and 12 mm stainless steel can be cut (Ghany & Newishy, 2005).

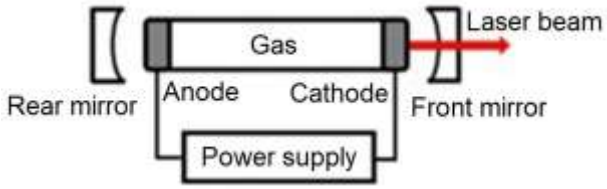


Figure 1. The structure of CO_2 laser system (Muangpool & Pullteap, 2018)

2.1.2. NdYAG laser cutting

This type of laser is widely used in various fields such as medicine, surgery, ophthalmology, and dentistry (Muangpool & Pullteap, 2018). It has a wavelength of 1.06 μm. It can be focused on small spots and allows for precise work. It has very low reflectivity on metals and possesses the ability to pass through glass (Powell & Kaplan, 2004).

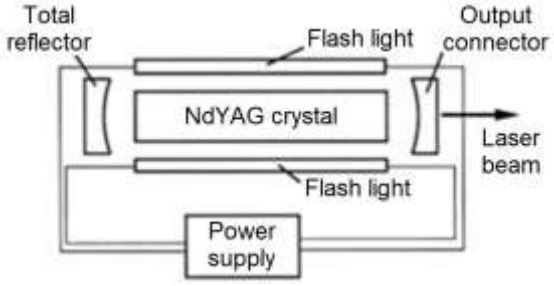


Figure 2. The structure of NdYAG laser system (Muangpool & Pullteap, 2018)

2.1.3. Fiber laser cutting

They produce a beam with a wavelength of 1.06 m. They provide quality results for materials thinner than 3 mm. They cut quickly and their edge quality is quite good. (Powell & Kaplan, 2012).

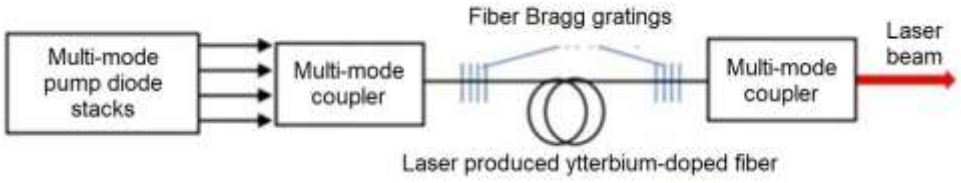


Figure 3. The structure of fiber laser system (Muangpool & Pullteap, 2018)

2.2. The structures of LBC benches

The structures of LBC machines vary among themselves. These machine structures also affect factors such as cutting quality, performance, and efficiency. Machines are classified based on the movement of the cutting laser head and/or the worktable. One of the most commonly used structural types is known as the flying optics system. In this system, the laser beam is generated from a fixed source, while the cutting head moves along the X and Y axes to perform the cutting process (Figure 11). Since the workpiece remains stationary, working with large-sized sheets becomes easier, and high cutting speeds can be achieved (Çelik et al., 2013).



Figure 4. LBC benches from Bystronic (Çelik et al., 2013)

In addition, in moving table systems, the laser source and the cutting head remain stationary, while the material to be cut is moved on the table. Since the optical path remains constant, the focal point of the laser beam is maintained, ensuring high precision especially in the cutting of small-sized parts (Ghany & Newishy, 2005).

2.3. The machining parameters of LBC method

The laser cutting process requires careful determination of numerous machining parameters depending on the material type, thickness, cutting type, and desired quality. These parameters directly affect cutting precision, surface quality and production efficiency (Steen & Mazumder, 2010; Yılmaz & Kaya, 2021). The key machining parameters commonly controlled in the laser cutting process are explained under subheadings.

2.3.1. Laser power

Laser power refers to the amount of energy transferred from the laser source to the material. There are two types of power: continuous wave (CW) and pulsed wave (PW). The average power density is calculated using the formula P/A beam, where P is the power and A is the laser beam area (Assuncao & Williams, 2013). High power levels enable the cutting of thick materials, while low-power systems are used in precision cutting applications (Powell, 1998). However, excessive power usage can lead to edge melting, burrs or discoloration, expansion of HAZ and an increase in kerf width (Çelik et al., 2013; Kumar & Yadav, 2015). Factors determining laser power include the type of laser source (CO_2 or fiber lasers), beam focusing quality, the thermal properties of the material, cutting speed and the use of assist gases (Suresh & Venkatesan, 2020).

2.3.2. Cutting speed

Cutting speed (mm/s or m/min) refers to the rate at which the laser head moves across the material. At very low speeds, heat buildup can cause burning or burr formation, while at excessively high speeds, complete cutting may not be achieved. The speed should be determined in a balanced manner along with material thickness and laser power (Yilbas, 2017).

2.3.3. Focus position

The focus position refers to the location of the laser beam's most concentrated point relative to the material surface. Typically, the focus is positioned on or just slightly below the surface of the material. Proper focusing enables the beam to narrow, resulting in cleaner and more precise cuts (Yılmaz & Kaya, 2021).

2.3.4. Assist gas type and pressure

The assist gas (O_2, N_2 or air) facilitates the removal of molten material from the cutting area and directly affects the cutting quality. Oxygen supports cutting through oxidation in materials like carbon steel, thereby increasing processing speed; whereas when cutting with nitrogen, no oxidation occurs at the cutting edge, resulting in a cleaner surface. The gas pressure determines the effectiveness of this cleaning and cooling effect (Ghany & Newishy, 2005).

2.3.5. Pulse frequency and pulse duration

In pulsed laser systems, pulse frequency (Hz) and pulse duration (μs) refer to the duration and repetition rate of the applied energy pulses. These parameters determine the edge quality and surface roughness, especially in fine cutting or micromachining (Powell, 1998; Steen & Mazumder, 2010). Higher pulse frequencies provide a smoother and more continuous cutting profile. However, very high frequencies can lead to material overheating and edge quality degradation (Rao et al., 2005). Pulse duration, on the other hand, determines how long each laser pulse is applied. Short pulse durations give better results, especially for thin materials and applications requiring micron-level precision, while longer pulse durations are preferred for deeper cuts (Buj-Corral, Costa-Herrero, & Domínguez-Fernández, 2021).

2.3.6. The distance between nozzle and workpiece (NTD)

The distance between the nozzle and the material surface is important for the effect of the assist gas and the focusing of the laser beam. The NTD is usually set between 0.5-2 mm. Too close distance may cause burrs. At too far distance, energy is dissipated and cutting depth may decrease (Krar & Gill, 2003). A shorter nozzle-to-workpiece distance allows the assist gas to reach the material surface more directly. This contributes to more effective cooling and less burr formation (Rao et al., 2005).

2.4. The Advantages and Disadvantages of LBC Method

2.4.1. Advantages

- LBC offers significant advantages over conventional machining methods due to its ability to process at high speed, operational precision, absence of tool wear and vibration, high accuracy and low processing cost (Steen & Mazumder, 2010; Yilbas, 2017).
- Fast machining time and good finished product quality can be achieved.
- Materials such as metals, plastics and ceramics of different types and thicknesses can be cut seamlessly with the laser. This provides flexibility, especially in multi-material production processes.
- Since LBC is a non-contact method, there is no need for special fixtures, apparatus or mechanical support systems according to the shape of the workpiece (Ghany & Newishy, 2005).

2.4.2. Disadvantages

- Due to the high heat generated during LBC, stress zones may form around the cutting edges.
- They cannot make blind hole formation.
- Investment and maintenance costs are high.
- Especially older generation laser systems, such as CO_2 lasers, can consume a lot of energy during operation. This can increase operating costs in the long run (Yilbas, 2017).

3. The Application Areas of LBC

3.1 Automotive and aerospace industry applications

LBC is widely used in the automotive (Figure 12) and aerospace industries to produce parts that require high precision and quality (Kumar & Singh, 2023). This technology offers advantages in the production of parts with complex geometries and in the processing of lightweight materials (Bogue, 2015; Rao & Kumar, 2023).



Figure 12. The LBC application in automotive industry (HGLASER, 2023)

3.2 Electronic applications

In the production of printed circuit boards (PCBs), LBC is highly preferred for high-precision drilling and cutting (Wang & Zheng, 2009). This method plays an important role in the production of small-scale components (Figure 13).

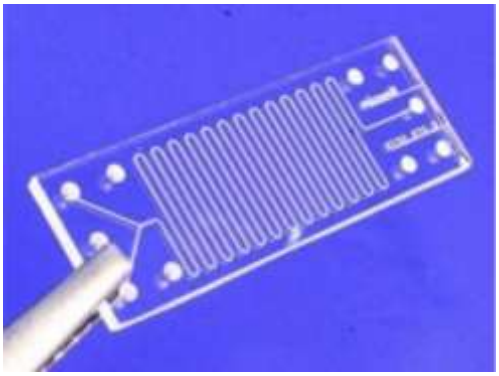


Figure 13. The PCB machined with LBC (Bogue, 2015)

3.3 Medical technologies applications

In the production of medical devices such as surgical instruments, stents and implants, LBC enables precision machining of biocompatible materials (Figure 14). CO_2 lasers are particularly preferred for cutting polymeric materials (Caiazzo et al., 2005).



Figure 14. The examples of LBC in medical areas (DeCesar & Boyle, 2022)

3.4 Prototyping applications

In rapid prototyping processes, LBC helps designers and engineers to quickly transform their ideas into physical models (Happonen, Stepanov, & Piili, 2015). This speed ups the product development process. Figure 15 shows a prototype product cut with LBC.



Figure 15. The prototyping example of LBC (Baison, 2024)

3.5 Biomaterials and tissue engineering applications

LBC technology is used in tissue engineering applications, for example in the production of three-dimensional scaffolds using polycaprolactone/hydroxyapatite composite polymer (Figure 16) (Kumar & Singh, 2023; Lasers in Materials Processing, 2019).



Figure 16. The machining moment of biomaterials with LBC (ESN Metal, n.d.)

3.6 Manufacturing industry applications

LBC offers tight tolerance, clean cuts in metal, plastic and composite sheets (Figure 17) thanks to the surface interaction of CO_2 and fiber laser welding (Atwee, Wibolo, & Wiryanta, 2023). Compared to traditional CNC methods, laser technology increases production efficiency by reducing edge roughness (Gökce et al., 2023).



Figure 17. The application of LBC in manufacturing industry (Yılmaz & Kaya, 2021)

3.7 Defense industry applications

LBC enables the efficient production of high-precision armor plates and parts with complex geometry in defense systems (Ahmed, Mohsin, & Ali, 2021). In addition, fiber and solid-state lasers are widely used in military training systems for target designation and distance measurement (Lazov, Teirumnieks, & Ghalot, 2021). LBC is one of the most frequently used manufacturing methods in defence industry projects. Cutting on CNC laser machines allows cutting of materials of different types, properties and thicknesses (Figure 18).

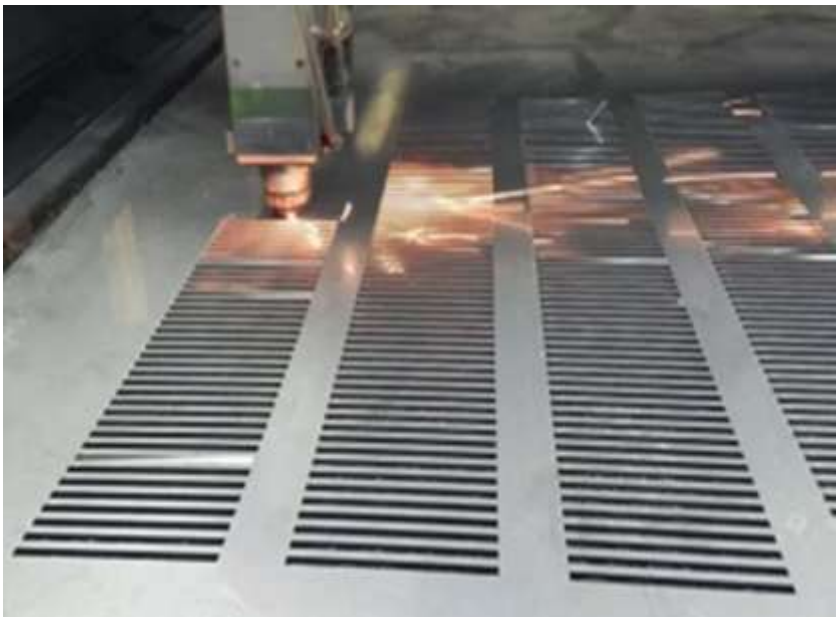


Figure 18. The sheet metal used in defense industry cutting with CNC LBC bench (Bersa Tech Makina, n.d.)

4. Conclusion

LBC is a method that works on the principle of localized melting and even vaporization by focusing high intensity beams with stimulated radiation emission on the surface of materials. In this study, detailed information about the types of LBC method, machining parameters (laser power, cutting speed, focus position, assist gas type, etc.), output performances (WRR, kerf width, kerf taper, surface roughness, HAZ width, etc.), machine structures, advantages-disadvantages and application areas are given. From the studies in the literature, important points about LBC are briefly summarized below:

- It was concluded that the kerf width increased significantly with increasing laser power and the cutting quality deteriorated.

- It is reported that as the cutting speed increases, the HAZ width decreases and, this has a positive effect on the cutting quality.

- It was reported that increasing the oxygen gas pressure has an improving effect on surface roughness.

- It has been reported that with the increase in laser power and cutting speed, the WRR increased, but the kerf width and surface roughness value also increased.

- When low pulse frequency is used in cutting processes, it is stated that the cutting surfaces are improved and the HAZ width is narrowed. When high pulse frequency is used, surface roughness is reported to increase.

- In the LBC method, it was reported that the type and pressure of the assist gas used affect the slag formation. It has been reported that using argon gas at low pressures keeps slag formation at lower levels and improves the cutting surface. It has also been reported that oxide and nitride formation can be minimized by using argon gas.

- The use of pulsed and continuous wave (CW) NdYAG lasers in the LBC method was found to be effective on cutting quality. It is stated that CW laser increases HAZ widths as more energy is transferred by thermal diffusion due to continuous energy input to the workpieces. The pulsed laser is reported to be suitable for more precise and burr-free cuts but, increases the processing time and energy consumption.

- In the LBC method, it was found that the laser beam focus position can be adjusted differently (below the surface, on the surface, above the surface). It was concluded that for most applications, the best cutting quality is achieved when focusing on the workpiece surface (f = 0).

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EFFECTS OF DIFFERENT NUTRIENT ELEMENT APPLICATIONS ON THE VEGETATIVE AND GENERATIVE DEVELOPMENT OF NARINCE AND KARAERIK GRAPE VARIETIES GROWN UNDER GREENHOUSE CONDITIONS

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ABSTRACT

This study was conducted in Erzurum, Türkiye, a region characterized by a continental climate, to evaluate the effects of various nutrient element applications on the growth of Narince and Karaerik grapevine cultivars of different ages (2 and 6 years) grown under greenhouse conditions. The aim was to explore the feasibility of grape cultivation under protected environments in high-altitude and cold-climate regions where open-field viticulture is restricted due to harsh climatic conditions. Following comprehensive soil analysis, nutrient solutions containing iron (Fe), zinc (Zn), nitrogen (N), amino acids, and selected trace elements were applied to the vines. The effects of these applications were assessed based on a range of vegetative and generative growth parameters, including number of shoots, shoot length, shoot diameter, number of leaves per shoot, leaf area, number of internodes, number of clusters, cluster width, cluster length, cluster weight, number of berries per cluster, berry width, berry length, and number of seeds per berry. Yield values were also recorded. The results revealed that the applied nutrient elements had statistically significant effects on plant development, depending on the grape variety and plant age. Notable differences were observed between Narince and Karaerik in terms of nutrient uptake and growth responses. These findings highlight the necessity of developing cultivar-specific fertilization strategies under greenhouse conditions.

Keywords: Grapevine, greenhouse, nutrient management, Narince, Karaerik

Introduction

Grapevine (*Vitis vinifera L.*), which has held a significant place throughout human history, maintains its commercial prominence both globally and in Türkiye due to its versatile uses. Beyond its consumption as fresh fruit, grapes are utilized for drying, winemaking (Çelik et al., 2012), molasses, grape juice, verjuice, and the preservation of vine leaves, all of which contribute to the high commercial value of viticulture (Soltekin et al., 2021). Grapes, which have existed for millions of years and include thousands of varieties and cultivars, are cultivated economically in many regions of Türkiye, a land that has witnessed the rise and fall of numerous civilizations throughout history. In Eastern Anatolia, the region with the highest elevation in the country, recent increases in dam constructions have led to a moderation of the local climate, creating limited yet suitable microclimatic zones for grape cultivation (Uyak et al., 2009; Sırlı et al., 2015).

Climate, which affects all living organisms, plays a critical role not only in the determination of areas suitable for plant production but also in influencing both yield and quality (Jones et al., 2004). As one of the most climate-sensitive crops, grapevines-especially when grown on their own roots-are known for their adaptability and resilience to adverse environmental conditions. However, climate remains one of the most decisive factors influencing the development and ripening of grapevines and therefore their economic viability in a given region (Çelik et al., 1998; Soltekin et al., 2021). Grapevines require approximately 1300 hours of annual sunshine to reach harvest maturity. Under the ongoing process of global climate change, some adverse changes are anticipated, especially in warmer regions. Nevertheless, these negative impacts on grapevine growth and development may be partially mitigated through appropriate cultural practices (Uyak et al., 2009; Küpe, 2012).

In some provinces of Eastern Anatolia, the lack of commercial viticulture is primarily due to prolonged winter temperatures that can damage grapevines. It is not the absolute low temperatures but the duration of exposure to these cold conditions that causes the most harm. For example, while sustained temperatures below -20°C can damage vines, in Erzincan, where minimum temperatures can drop to -32.5°C, the relatively short duration of cold periods has allowed grapevines to survive, enabling commercial viticulture to be practiced (Odabaş, 1980).

Erzurum, characterized by a harsh continental climate, has traditionally been considered unsuitable for grape cultivation. However, in recent years, protected cultivation systems—designed to create controlled environments independent of outdoor conditions—have emerged as a promising solution. These systems not only extend the growing season but also provide optimal conditions for plant development. Grapevine cultivation under cover enables precise fertilization, timely pest and disease control, and overall improved crop management. In cold-climate regions like Erzurum, protected cultivation offers significant advantages and holds great potential for the sustainable development of viticulture.

Thanks to their high adaptation capacities, the Karaerik and Narince grape cultivars are believed to be economically viable under protected cultivation in Erzurum's central conditions, provided that appropriate fertilization programs are applied.
This study aims to investigate the effects of different compositions and doses of plant nutrients on the vegetative and generative development, as well as the yield parameters, of 2- and 6-year-old Karaerik and Narince grapevines grown under protected conditions in Erzurum. Based on the results, specific plant nutrient recommendations for these grape cultivars under Erzurum's protected cultivation conditions will be provided.

Materials and Methods

Material

This study was conducted in 2024 under the ecological conditions of Erzurum city center, within a 300-square-meter unheated greenhouse located at the Plant Production Research and Application Center. The greenhouse was constructed with a steel frame structure, covered with transparent polycarbonate panels, and equipped with a drip irrigation system.

As plant material, two grape cultivars were utilized: 'Karaerik', a local variety traditionally grown in the Erzincan region, and 'Narince', a widely preferred cultivar in the Tokat province.

In March, two-year-old own-rooted saplings of both Narince and Karaerik cultivars were planted in the greenhouse. Additionally, six-year-old own-rooted vines of the same cultivars, already established within the same greenhouse, were included in the experimental design (Figure 1).



Figure 1. A view of the greenhouse and vines where the study was conducted

Method

In the greenhouse, a balanced organomineral basal fertilizer was first applied to the vines. This basal fertilizer contained 11% nitrogen (N), 11% phosphorus (P_2O_5), 11% potassium (K_2O), 11% sulfur (SO_3), 0.2% zinc (Zn), and 15% organic matter (composition: 11-11-11 + 11SO_3 + micronutrients).

Subsequently, at various phenological stages, additional fertilization treatments were applied, including micronutrient-enriched formulations containing boron (B), copper (Cu), iron (Fe), molybdenum (Mo), manganese (Mn), and zinc (Zn). Applications also included 6% EDDHA-chelated powdered iron, 8% liquid zinc sulfate, and 32% liquid nitrogen fertilizer (composed of 16% urea nitrogen, 8% ammonium nitrogen, and 8% nitrate nitrogen). Furthermore, an organic liquid fertilizer derived from plant-based materials was used, containing 45% organic matter, 3% organic nitrogen, 14% free amino acids, and 25% organic carbon.

All fertilizers were applied with irrigation water at a rate of 1 liter per vine for 2-year-old plants and 2 liters per vine for 6-year-old vines. Control plants received the same amount of plain water without any added fertilizers.

At the beginning of the study, soil samples were collected and analyzed for key physicochemical properties, including soil texture, pH, salinity, lime content, organic matter level, and concentrations of ten essential plant nutrients. Based on these soil characteristics, fertilization programs were developed accordingly.

Table 1. Greenhouse soil analysis results before fertilizer applications

Measurements	**Unit**	**Analysis Result**	**Evaluation**
Structure		41,8	Loamy
pH		7,92	Slightly Alkaline
Salinity	%	0,01	Without Salt
Chalkiness	%	6,98	Middle
Organic Matter	%	0,473	Very Little
Nitrogen	%	0,02	Very Poor
Phosphorus	kg/da	6,23	Middle
Potassium	kg/da	176,68	More
İron	ppm	1,69	Little
Zing	ppm	0,14	Very Little
Copper	ppm	0,43	Sufficient
Manganese	ppm	1,74	Sufficient
Calcium	ppm	6.938	More
Magnesium	ppm	552,8	More
Sodium	ppm	43,8	Sufficient

On May 3, 2024, a standard application of 0.5 kg of balanced organomineral basal fertilizer (11-11-11 + 11SO_3 + ME) was applied to all two-year-old Narince and Karaerik grapevines. Subsequently, a dose of 1 kg of the same basal fertilizer was uniformly applied to all six-year-old vines of both cultivars. The Narince and Karaerik vines used in the experiment were divided into four treatment groups, including a control, with each group consisting of two vines. This grouping was established separately for each cultivar and age class (Table 2 and 3).

Table 2. Treatment groups and fertilizer compositions for 2-year-old grapevines (per vine)

Group	Fertilizer Composition	Water Volume	Application Method
1	1.5 g micronutrients + 20 cc nitrogen	1 L	Fertigation
2	1 g Fe + 1 cc Zn + 20 cc nitrogen	1 L	Fertigation
3	1 g Fe + 1 cc Zn + 20 cc nitrogen + 20 cc amino acids	1 L	Fertigation
4	Control (only water)	1 L	Fertigation

Table 3. Treatment groups and fertilizer compositions for 6-year-old grapevines (per vine)

Group	Fertilizer Composition	Water Volume	Application Method
1	3 g micronutrients + 40 cc nitrogen	2 L	Fertigation
2	2 g Fe + 2 cc Zn + 40 cc nitrogen	2 L	Fertigation
3	2 g Fe + 2 cc Zn + 40 cc nitrogen + 40 cc amino acids	2 L	Fertigation
4	Control (only water)	2 L	Fertigation



Figure 2. Some images of fertilizer application

Morphological observations were initiated in May 2024 and continued throughout the vegetative growth period for all treatment groups on both Narince and Karaerik grapevines.

Yield measurements and pomological analyses were conducted specifically on the six-year-old Karaerik and Narince cultivars.

Findings and Discussion

Due to their perennial nature, fruit crops are more vulnerable to the impacts of climate change. Each fruit species has specific climatic requirements to achieve optimal vegetative and generative development (Luedeling et al., 2011). Sudden and abnormal fluctuations in air temperature can negatively affect the growth and development of fruit crops (Omoto et al., 1990; Legave et al., 2008). Among climatic factors, temperature plays a critical role-either directly or indirectly-at every stage of the vegetative and generative development of grapevines (Li et al., 2023). Kimura et al. (1984), demonstrated in their study on the Kyoho grape variety that using plastic covering systems can protect grapevines from adverse climatic conditions.

In this study conducted under unheated greenhouse conditions in Erzurum, the effects of different concentrations of nitrogen (N), iron (Fe), zinc (Zn), plant-based amino acids, and a mixed group of micronutrients on the Karaerik and Narince grape cultivars were investigated. The study evaluated vegetative development parameters at two distinct growth stages for both two- and six-year-old vines, while generative development parameters and yield data were assessed specifically for the six-year-old Karaerik and Narince cultivars.

As shown in **Table 4**, different fertilizer treatments had varying effects on the vegetative development parameters of the two-year-old Karaerik vines. While both the control and Group 2 (1 g Fe + 1 cc Zn + 20 cc N in 1 L water) were found to be more effective in terms of shoot number and shoot diameter, Group 1 (1.5 g micronutrient mix + 20 cc N in 1 L water) and Group 3 (1 g Fe + 1 cc Zn + 20 cc N + 20 cc plant-based amino acids in 1 L water) were more influential in promoting shoot length, number of leaves per shoot, and leaf blade size.

Table 4. Effects of different fertilizer applications on vegetative growth parameters of 2-year-old Karaerik grape variety

Aplications	Shoot Number (item)		Shoot Diameter (cm)		Number of Leaves in the Shoot (item)		Leaf Diameter (cm)		Shoot Lenght (cm)	
	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period
Control	2	2,5	0,17	0,21	6,0	11,9	4,3	5,1	7,0	9,4
3. Application	1	1	0,325	0,51	23,5	57,5	9,1	10,4	26,8	34,6
2. Application	1,5	1,5	0,28	0,36	15,0	30,3	9,7	8,0	10,6	19,5
1. Application	1	1	0,37	0,51	27,5	44,0	8,7	10,1	19,8	38,9

As shown in **Table 5**, the different fertilizer treatments exhibited varying effects on the vegetative growth parameters of the two-year-old Narince grapevine cultivar. In terms of shoot number and shoot diameter, the control group and Group 1 (1.5 g micronutrient mix + 20 cc nitrogen in 1 L of water) were found to be more prominent. However, for shoot length, number of leaves per shoot, and leaf blade area, Group 2 (1 g iron + 1 cc zinc + 20 cc nitrogen in 1 L

of water) and Group 3 (1 g iron + 1 cc zinc + 20 cc nitrogen + 20 cc plant-based amino acids in 1 L of water) demonstrated greater effectiveness.

Table 5. Effects of different fertilizer applications on vegetative growth parameters of 2-year-old Narince grape variety

Aplications	Shoot Number (item)		Shoot Diameter (cm)		Number of Leaves in the Shoot (item)		Leaf Diameter (cm)		Shoot Lenght (cm)	
	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period
Control	3,5	3,5	0,24	0,325	6,5	11,4	6,3	8,3	13,0	15,6
3. Application	1,5	2	0,345	0,45	14,5	15,8	10,3	10,4	43,1	53,6
2. Application	1,5	2	0,695	0,585	13,3	21,5	9,0	11,0	36,2	35,3
1. Application	3	3	0,22	0,365	11,0	18,5	9,2	10,4	26,4	24,9

Table 6. Effects of different fertilizer applications on vegetative growth parameters of 6-year-old Karaerik grape variety

Aplications	Shoot Number (item)		Shoot Diameter (cm)		Number of Leaves in the Shoot (item)		Leaf Diameter (cm)		Shoot Lenght (cm)	
	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period
Control	25,5	32	2,45	2,34	91,0	140,0	21,7	30,9	330,8	381,4
3. Application	23	23,5	2,38	2,43	150,8	173,0	27,2	27,6	415,1	425,9
2. Application	12,5	16	1,295	1,42	127,3	143,3	23,4	23,9	260,9	372,4
1. Application	12,5	12,5	1,53	1,92	131,8	221,5	24,6	27,5	361,8	392,1

In the six-year-old Karaerik grapevine cultivar, vegetative growth parameters measured at two different stages showed that all three fertilizer treatments resulted in increased growth compared to the control group. Group 3 (1 g iron + 1 cc zinc + 20 cc nitrogen + 20 cc plant-based amino acids in 1 L of water) demonstrated significant growth in shoot length and leaf diameter, while Group 1 (1.5 g micronutrient mix + 20 cc nitrogen in 1 L of water) was more effective in leaf formation on the shoots (Table 6).

Table 7. Effects of different fertilizer applications on vegetative growth parameters of 6-year-old Narince grape variety

Aplications	Shoot Number (item)		Shoot Diameter (cm)		Number of Leaves in the Shoot (item)		Leaf Diameter (cm)		Shoot Lenght (cm)	
	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period	1. period	2. period
Control	12,5	13	1,535	1,66	63,5	90,5	21,3	22,1	300,4	354,7
3. Application	16,5	16,5	1,07	1,17	66,0	105,3	21,9	25,1	369,4	405,8
2. Application	17,5	17,5	1,43	1,67	82,5	123,5	26,1	28,4	369,1	433,4
1. Application	15	15	1,355	1,37	82,0	117,8	26,6	27,5	393,1	427,8

In the six-year-old Narince grapevine cultivar, vegetative growth parameters measured at two different stages showed that all three fertilizer treatments resulted in increased growth compared to the control group. Fertilizer treatments 1 and 2 were found to be more effective than treatment 3 in all vegetative growth parameters, except for the shoot count parameter (Table 7).

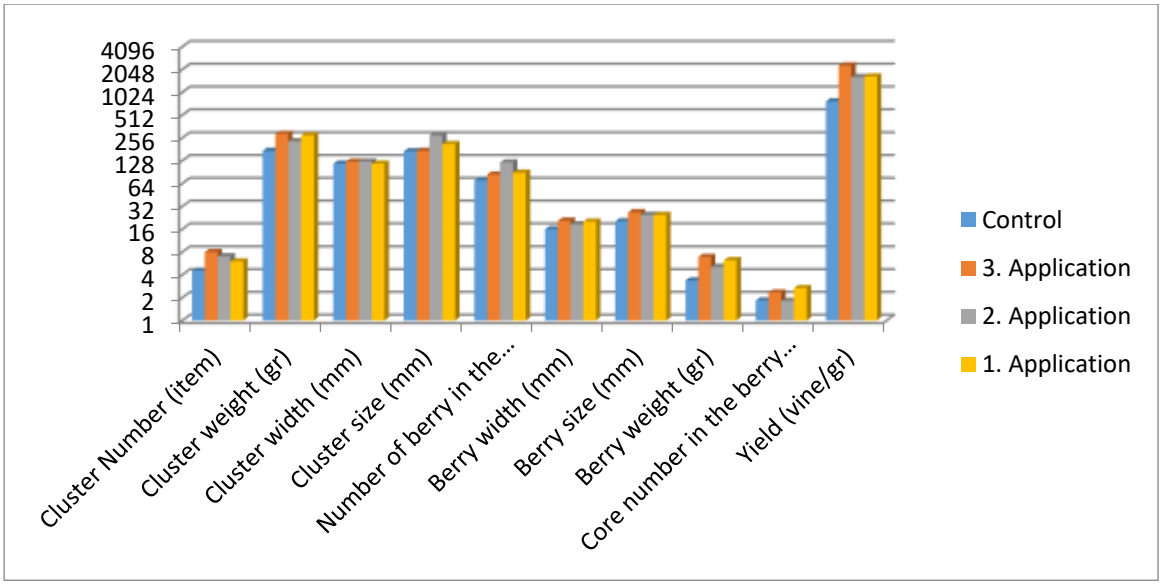
Similarly, Kara and Sabir (2010), conducted a study to assess the effects of a commercial organic fertilizer containing CaO, MgO, Fe2O3, SiO2, K2O, N, P, Cu, Ni, and Zn on shoot development in certain one-year-old grape rootstocks (140 Ru, 99 R, and 41 B). The results of the study indicated that the commercial organic fertilizer accelerated the vegetative development of the grapevine, making the seedlings healthier and more resilient.

Likewise, Özdemir (2018), conducted a study in the ecological conditions of Diyarbakır to evaluate the effects of various commercial organic and organomineral fertilizers on shoot development in the Boğazkere and Öküzgözü grape cultivars. The results indicated that the commercial fertilizer containing 5% N, 5% P2O5, 0% K2O, and microelements (ME) had a more significant effect on the shoot development of the Öküzgözü cultivar compared to other fertilizers, while the commercial fertilizer with 5% N, 5% P2O5, 5% K2O, and ME produced the highest shoot length in the Boğazkere cultivar.

Table 8. Table view of the effects of different fertilizer applications on generative growth parameters of 6-year-old Karaerik grape variety

Applications	Cluster Number (item)	Cluster weight (gr)	Cluster width (mm)	Cluster size (mm)	Number of berry in the cluster (item)	Berry width (mm)	Berry size (mm)	Berry weight (gr)	Core number in the berry (item)	Yield (vine/gr)
Control	4,5	172,60	116,86	170,21	70,5	15,95	20,34	3,35	1,83	776,68
3. Application	8	288,50	123,93	172,54	84	20,67	26,73	6,87	2,33	2.308,2
2. Application	7	231,43	124,54	277,10	121,5	18,45	24,60	5,06	1,82	1.620,01
1. Application	6	275,65	117,27	212,43	89	20,15	24,61	6,21	2,67	1.653,9

Table 9. Column graph view of the effects of different fertilizer applications on generative growth parameters of 6-year-old Karaerik grape variety

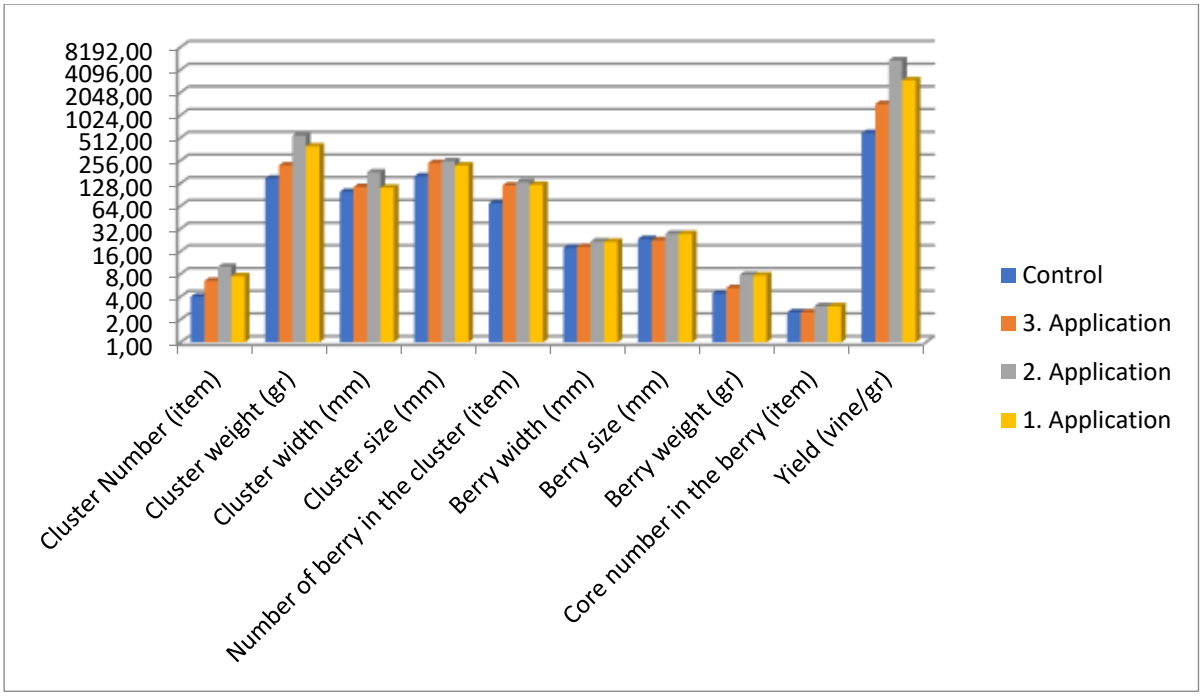


The different fertilizer applications had a significant effect on cluster number, cluster weight, cluster width, cluster length, berry number per cluster, berry width, berry length, berry weight, seed number per berry, and yield values in the Karaerik grape cultivar, compared to the control group. When examining Tables 8 and 9, it was observed that fertilizer treatment 3 had the highest values for berry width, berry length, number of berries per cluster, number of clusters per vine, cluster weight, and yield. Furthermore, fertilizer treatments 1 and 2 resulted in similar outcomes for several parameters.

Table 10. Table view of the effects of different fertilizer applications on generative growth parameters of 6-year-old Narince grape variety

Applications	Cluster Number (item)	Cluster weight (gr)	Cluster width (mm)	Cluster size (mm)	Number of berry in the cluster (item)	Berry width (mm)	Berry size (mm)	Berry weight (gr)	Core number in the berry (item)	Yield (vine/gr)
Control	**4,00**	**148,16**	**98,16**	**158,38**	**69,50**	**17,92**	**23,38**	**4,44**	**2,50**	**592,64**
3. Application	**6,50**	**220,71**	**114,22**	**237,21**	**119,50**	**18,39**	**22,43**	**5,23**	**2,50**	**1434,58**
2. Application	**10,00**	**546,43**	**177,99**	**250,32**	**131,50**	**21,65**	**27,32**	**7,78**	**3,00**	**5464,30**
1. Application	**7,50**	**395,27**	**111,65**	**220,10**	**122,00**	**21,47**	**27,39**	**7,71**	**3,00**	**2964,49**

Table 11. Column graph view of the effects of different fertilizer applications on generative growth parameters of 6-year-old Narince grape variety



It was observed that different fertilizer applications had significant effects on cluster number, cluster weight, cluster width, cluster length, berry number per cluster, berry width, berry length, berry weight, seed number per berry, and yield values in the Narince grape cultivar compared to the control group. Examination of Tables 10 and 11 revealed that fertilizer treatment 2 resulted in the highest values for berry width, berry length, number of berries per cluster, number of clusters per vine, cluster weight, and yield. Fertilizer treatments 1 and 3, on the other hand, produced similar outcomes across several parameters.

Conclusion and Recommendations

The findings of this study indicate that, for optimal growth and development in viticulture, essential plant nutrients must be present in the soil at adequate levels. However, it should not be overlooked that the type and amount of nutrients to be applied in vineyards can vary depending on multiple factors such as soil properties, climate conditions, rootstock, grape variety, and irrigation system. In order to determine the fertilizer requirements of vineyards accurately, soil and leaf analyses are essential. The results demonstrated that the type of applied nutrients and vine age had significant effects on vegetative development. Distinct differences were observed between Narince and Karaerik grape cultivars in terms of nutrient uptake and developmental responses. These findings underscore the need to develop cultivar-specific fertilization strategies under protected cultivation conditions.

Overall, the outcomes of this research contribute to the optimization of fertilization programs for grape production under cold climate greenhouse conditions. Furthermore, it provides a valuable reference for future research and cultivation practices involving Narince and Karaerik grape cultivars.

Thanks and Information Note

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ASSESSMENT OF CLIMATE INDICES IN BINGOL PROVINCE

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ABSTRACT

This study aims to provide a comprehensive and multidimensional assessment of the climate characteristics of Bingöl Province, located in Eastern Anatolia, Turkey. Using long-term meteorological data from 1991 to 2021, the study applies classical climate classification indices (De Martonne, Erinç, Thornthwaite, Aydeniz, Köppen, and Köppen-Trewartha) alongside 27 ETCCDI (Expert Team on Climate Change Detection and Indices) indicators to evaluate extreme climate events. The findings reveal that Bingöl has a transition-type climate with characteristics ranging from semi-arid to semi-humid, showing increased variability and intensity of seasonal extremes, such as summer droughts and intense spring precipitation. The study highlights the importance of integrating multi-index climate analyses in regional planning and climate adaptation strategies.

Keywords: Bingöl, climate classification, ETCCDI, extreme weather, climate change, drought

BİNGÖL İLİNİN İKLİM ÖZELLİKLERİNİN FARKLI İKLİM İNDİSLERİNE VE DEĞİŞEN İKLİM OLAYLARINA GÖRE DEĞERLENDİRİLMESİ

ÖZET

Bu çalışma, Türkiye'nin Doğu Anadolu Bölgesi'nde yer alan Bingöl ilinin iklim özelliklerini kapsamlı ve çok boyutlu bir şekilde değerlendirmeyi amaçlamaktadır. 1991–2021 dönemine ait uzun yıllara dayalı meteorolojik veriler kullanılarak; De Martonne, Erinç, Thornthwaite, Aydeniz, Köppen ve Köppen-Trewartha gibi klasik iklim sınıflandırma indislerinin yanı sıra, aşırı iklim olaylarını değerlendirmeye yönelik 27 ETCCDI (İklim Değişikliği Tespiti Uzman Grubu İndisleri) göstergesi uygulanmıştır. Bulgular, Bingöl'ün yarı kurak ile yarı nemli arasında geçiş özellikleri gösteren bir iklime sahip olduğunu, mevsimsel uç olayların (yaz kuraklıkları ve ilkbahar yağışlarının şiddetlenmesi gibi) artan bir değişkenlik ve yoğunlukla gözlendiğini ortaya koymuştur. Çalışma, bölgesel planlama ve iklim uyum stratejilerinde çoklu indeks analizlerinin entegre edilmesinin önemine vurgu yapmaktadır. Eğer ileriye yönelik olarak gerekli tedbirler alınmazsa ilin çok yakın zamanda tamamen kurak bir yapıya evrilme olasılığının oldukça yüksek olduğu belirlenmiştir.

Anahtar Kelimeler: Bingöl, iklim sınıflandırması, ETCCDI, aşırı hava olayları, iklim değişikliği, kuraklık

1. Giriş

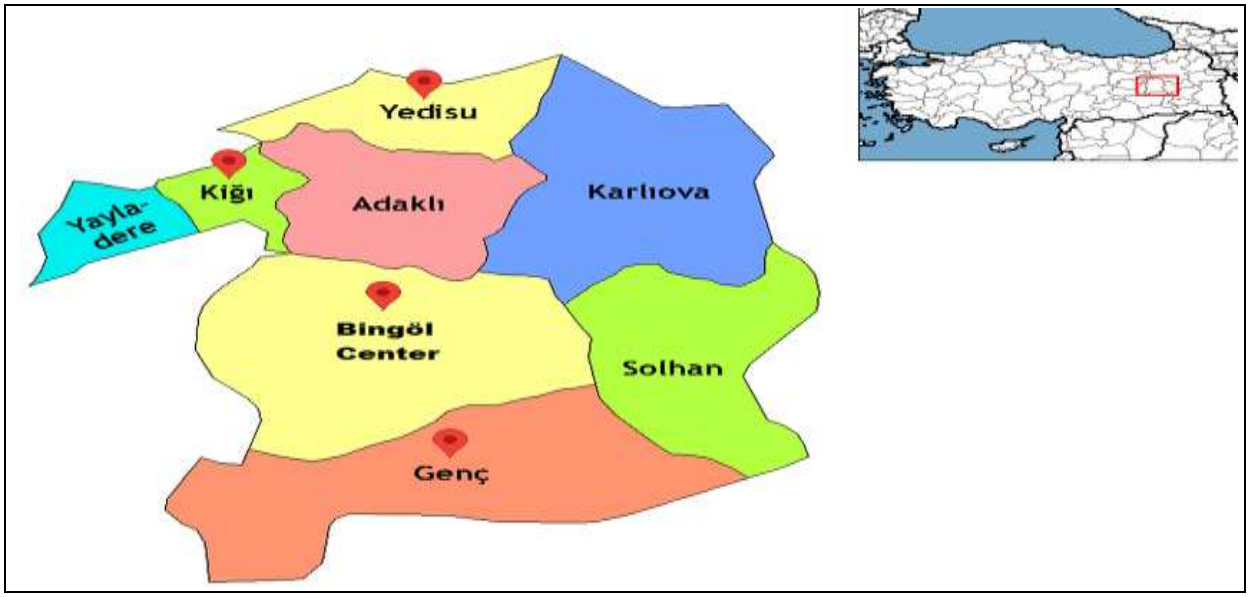
İklim, doğal sistemleri ve insan yaşamını doğrudan etkileyen temel çevresel bir faktördür. Sıcaklık, yağış, nem ve rüzgâr gibi meteorolojik değişkenler; özellikle tarım, ormancılık, su kaynakları yönetimi ve kırsal kalkınma gibi alanlarda belirleyici rol oynamaktadır. Türkiye gibi farklı coğrafi bölgeleri içeren ülkelerde iklimsel koşullar büyük farklılıklar gösterebilir ve bu değişkenlik, yerel kalkınma politikalarının oluşturulmasında kritik bir unsurdur.

Bingöl ili, Doğu Anadolu Bölgesi'nin Yukarı Fırat bölümünde yer almaktadır. Yüksek dağlar ve derin vadilerle şekillenen engebeli topografyası, mikroklimatik farklılıkların ortaya çıkmasına neden olmakta ve iklim yapısının çok boyutlu incelenmesini gerektirmektedir. Türkiye son yıllarda iklim değişikliğinin etkisini farklı şekillerde ve derinden hissetmeye başlamıştır. Doğu Anadolu bölgesi illeri de bundan etkilenmektedir. Bingöl ili konum olarak özel bir yerde yer almakta ve nemli iklime sahip olmasıyla bilinmektedir. Ancak son yıllarda il dengesi ve düzensiz yağışlar, sıcaklığın artışı ile kuraklaşmaya başlaması ciddi sorunlar oluşturmaya başlamıştır. Bu çalışmanın amacı, Bingöl iklimini hem genel iklim özelliklerini hem de aşırı hava olaylarını değerlendiren çok sayıda indeks ve göstergeye göre incelemektir.

2. Materyal ve Yöntem

2.1 Çalışma Alanı

Bingöl, 38°27′–40°27′ doğu boylamları ve 38°30′–40°27′ kuzey enlemleri arasında yer almakta olup, 8.125 km²'lik bir alanı kapsamaktadır. Ortalama deniz seviyesinden yüksekliği yaklaşık 1.200 metredir. Harita Gene Müdürlüğünden alınan harita Şekil 1'de verilmektedir Görüleceği gibi il konum olarak önemli bir yerde bulunmaktadır.



Şekil 1. Bingöl ilinin Türkiye'deki konumu (HGM, 2025)

2.2 Veri Seti

Çalışmada 1991–2021 dönemine ait aylık sıcaklık ve yağış verileri kullanılmıştır. Bu veriler, Türkiye Devlet Meteoroloji İşleri Genel Müdürlüğü'ne bağlı Bingöl Meteoroloji İstasyonu'ndan temin edilmiştir. Verilerin doğruluğu ve sürekliliği kontrol edilmiştir.

2.3 Uygulanan İklim İndeksleri

a) De Martonne Kuraklık İndeksi

Bu indis, yıllık yağış miktarı ile ortalama yıllık sıcaklık değerlerinin oranına göre bölgenin kuraklık durumunu belirler. 10'un altında çıkan değerler kurak iklimi, 10–20 arası yarı kurak iklimi, 20–30 arası yarı nemli iklimi göstermektedir.

b)Erinç Yağış Etkinlik İndeksi

Bu indeks, sıcaklık ve yağış arasındaki ilişkiyi daha bölgesel gerçekliklere uygun şekilde ölçmektedir. Türkiye koşullarına özel olarak geliştirilmiştir. Yarı nemli iklim koşulları için indeks değerleri genellikle 20–40 arasında yer alır.)

c)Thornthwaite İklim Sınıflandırması

Sıcaklık, yağış ve potansiyel evapotranspirasyon verileri kullanılarak hesaplanır. Nemlilik indeksi (Im) değerine göre iklim; çok nemli, nemli, yarı nemli, yarı kurak ve kurak olarak sınıflandırılır. Ayrıca sıcaklık bazlı olarak mezotermal veya mikrotermal gibi sınıflara ayrılır

d)Aydeniz İklim İndeksi (Türkiye'ye özgü)

Aydeniz iklim sınıflaması, aylık yağış ve sıcaklık verilerinin kullanıldığı, Türkiye'ye özgü geliştirilen bir sistemdir

e)Köppen ve Köppen-Trewartha Sınıflandırmaları

Köppen sistemi, sıcaklık ve yağış mevsimselliğine göre dünyanın iklimlerini harflendirme yoluyla sınıflandırır. Bingöl, yaz kuraklığı ve kış yağışları nedeniyle tipik bir "Csa" iklimi (Akdeniz iklimi – sıcak yazlar) özellikleri gösterir. Ancak kış sıcaklıklarının düşüklüğü ve kar yağışı nedeniyle bu sınıfa tam olarak uymamakta, "soğuk Akdeniz geçiş zonu" olarak yorumlanabilir.

> Csa (Akdeniz) iklimi özellikleri:

En sıcak ay ort. > 22°C

En soğuk ay ort. 0–18°C arası

Yaz kuraklığı belirgin

Yıllık yağış 500–1000 mm arasında

Bu sistem, Köppen'e benzer ama yıllık sıcaklık ortalamaları yerine daha detaylı mevsimsel sıcaklık analizleriyle sınıflama yapar. Köppen-Trewartha'ya göre Bingöl, "Dca" olarak sınıflandırılır:

> Dca İklimi Özellikleri:

Ilıman karasal iklim

En az 8 ay > 10°C

En soğuk ay < 0°C

Yazları sıcak ve kurak, kışları sert ve karlı

Bu sınıflama, Bingöl'ün yüksek rakımı ve karasal etkilerle şekillenen mevsimsel sıcaklık farklarını daha doğru şekilde yansıtır.

f) ETCCDI Tabanlı Aşırı İklim Göstergeleri (CSDI, FD0, GSL, ID0, SU25, TN10p, TN90p, TR20, TX10p, TX90p, TXn, TXx, CDD, CSDI, CWD, DTR, PRCPTOT, R10mm, R20mm, R95p, R99p, RX1day ve RX5day**)**

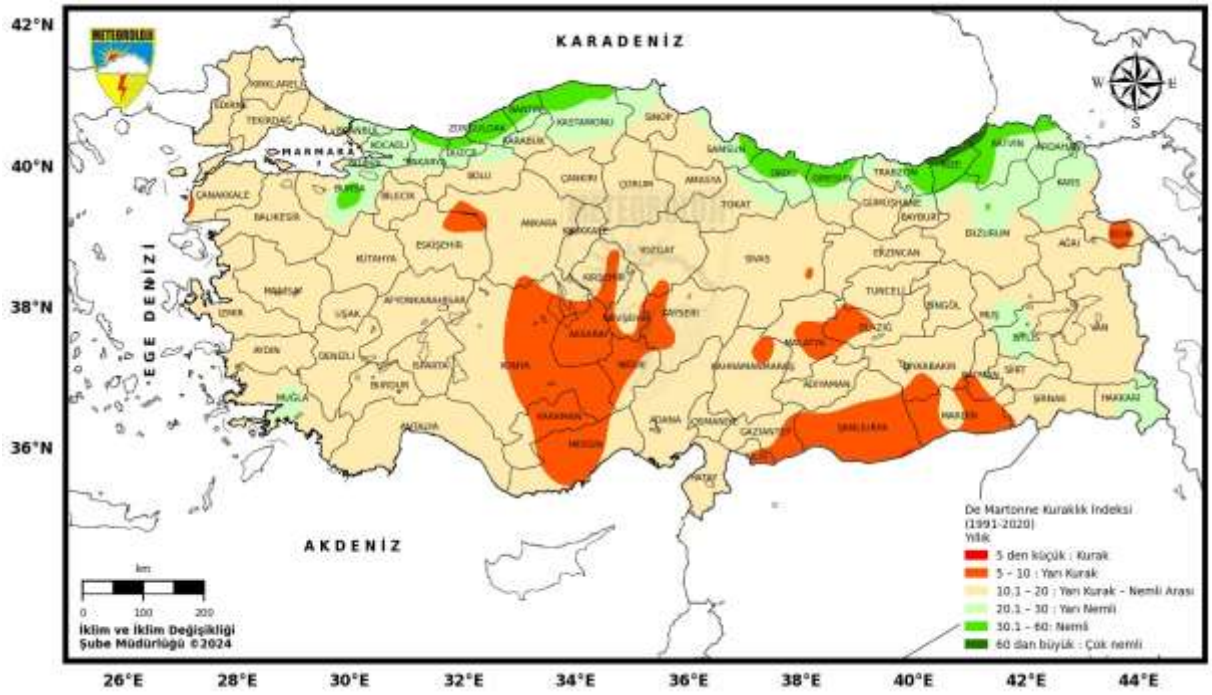
3. Bulgular ve Tartışma

3.1 Genel İklim Özellikleri

Yıllık ortalama sıcaklık 12,8°C, yıllık ortalama yağış miktarı yaklaşık 830 mm'dir. En yüksek yağış ilkbaharda (Mart–Nisan), en düşük yağış ise yaz aylarında (Temmuz–Ağustos) gerçekleşmektedir.

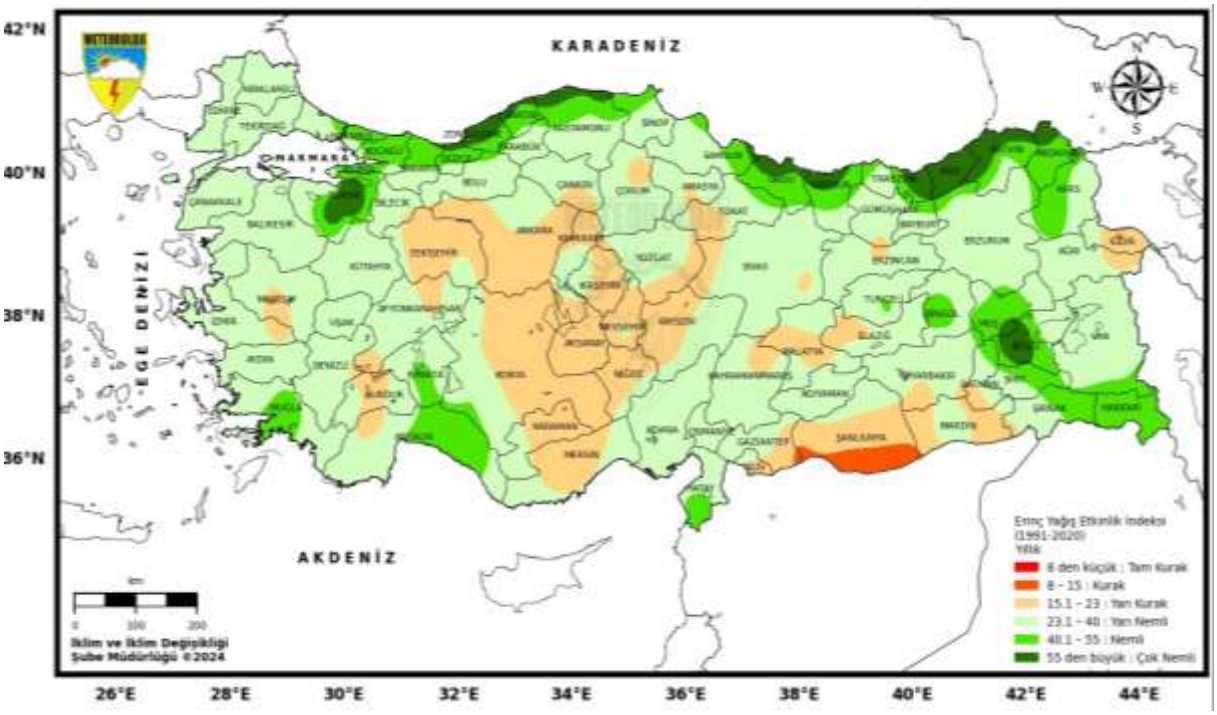
3.2 Klasik İklim Sınıflandırma Sonuçları

De Martonne İndeksi: Bingöl genellikle "yarı kurak" sınıfındadır. 2000 ve 2014 yıllarında kurak sınıra yaklaşmıştır (Şekil 2). Şekil incelendiğinde ilin genel olarak yarı kurak-nemli arasında olduğu ancak kurak alana daha yakın durduğu görülecektir.



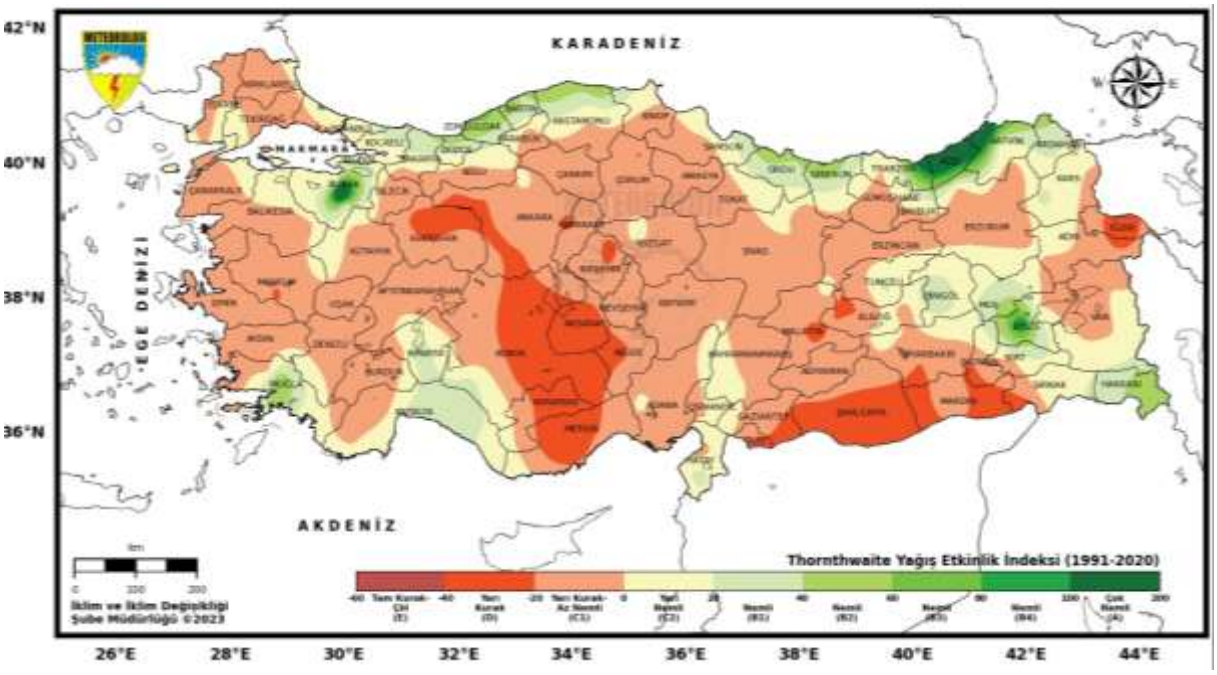
Şekil 2. Bingöl ilinin De Martonne İndeksine göre görünüşü (MGM, 2024)

Erinç İndeksi: İl, "yarı nemli" özellik göstermektedir. 1999 ve 2018 gibi yıllarda değerler düşmüş, değişkenlik artmıştır. Şekil 3'de bu durum gösterilmektedir. Bingöl merkez ilçe ve çevresi nemli bölge olurken, diğer alanlar ise yarı nemli olarak belirlenmiştir.



Şekil 3. Bingöl ilinin Erinç İndeksine göre görünüşü (MGM, 2024)

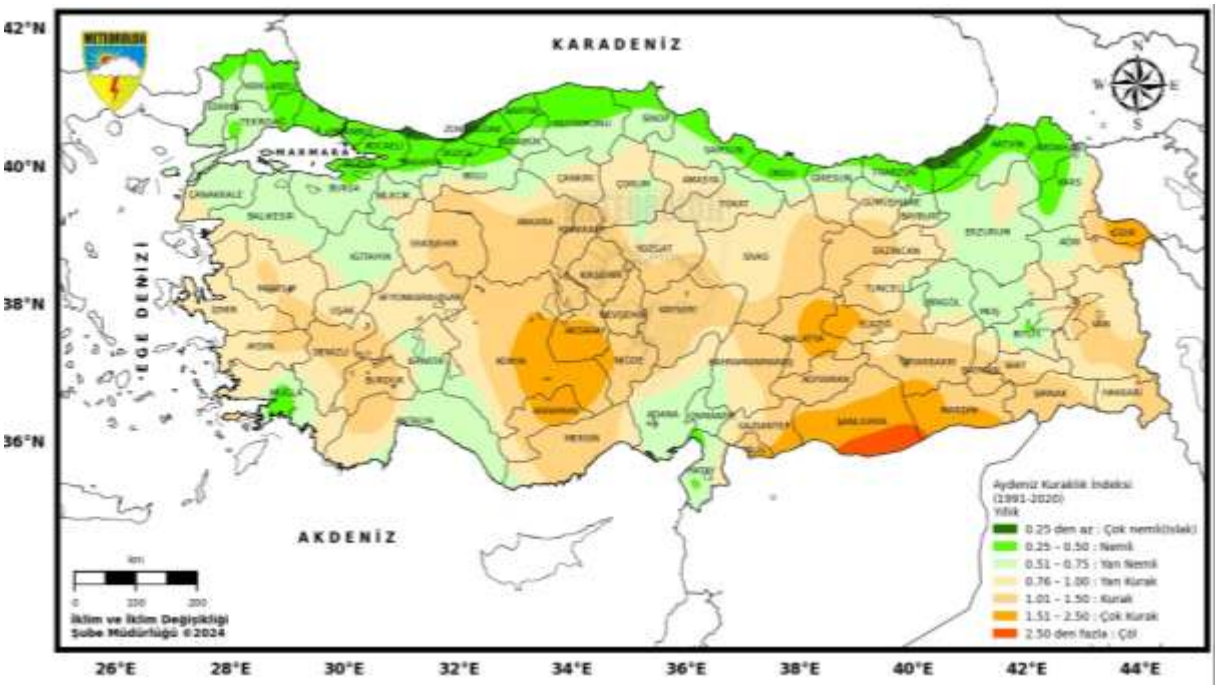
Thornthwaite indeksi: Bu indekse göre genel durum Şekil 4'de gösterilmektedir. Yarı nemli ve ikinci derece mesotermal sınıfta yer almakta; yaz aylarında belirgin su açığı mevcuttur. Yarı nemli olması kurağa yaklaştığının gösterebilmektedir. Alınacak tedbirlere göre bu değişebilecektir.



Şekil 4. Bingöl ilinin Thornthwaite İndeksine göre görünüşü (MGM, 2024)

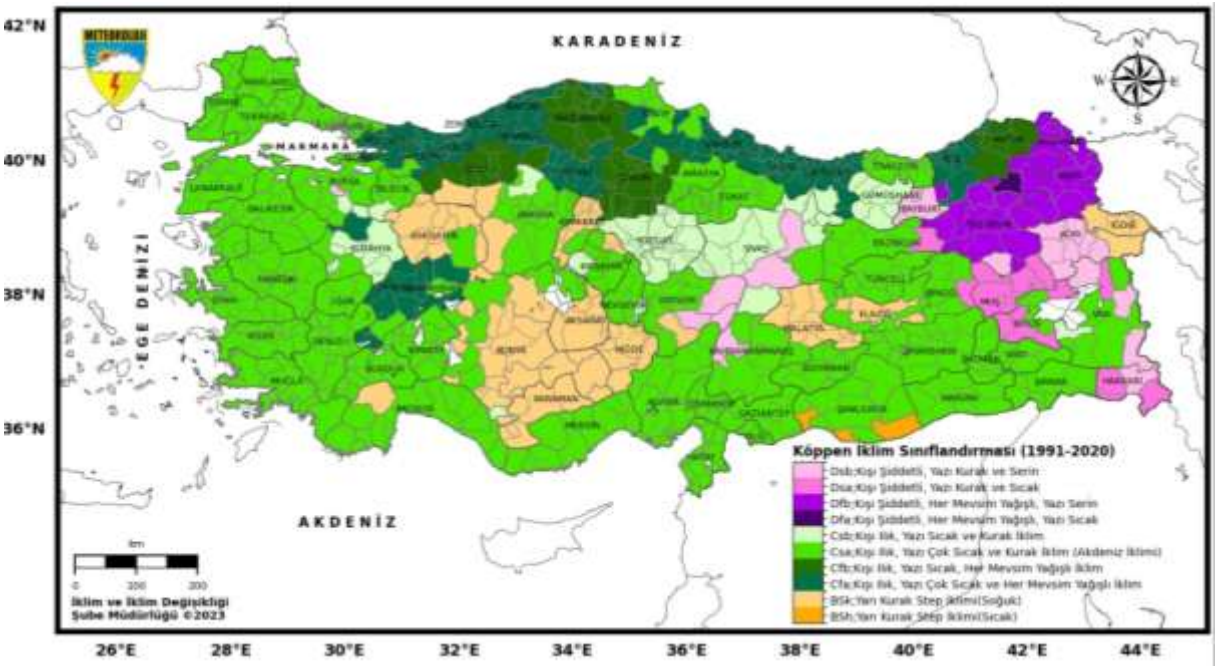
Aydeniz indeksi: Hesaplanan indeks değeri (~437), Bingöl'ü kış yağışlarının yüksek olması nedeniyle "çok nemli" sınıfa yerleştirmektedir (Şekil 5); ancak mevsimsel kuraklık da

gözlenmektedir. Mevsimsel kruaklığın son yıllarda belirgin şekilde artması geelcek açıdan endişe vericidir.



Şekil 5. Bingöl ilinin Aydeniz İndeksine göre görünüşü (MGM, 2024)

Köppen ve Köppen-Trewartha indeksi: Köppen'e göre Bingöl Csa (Akdeniz iklimi), Trewartha'ya göre ise Dca (ılıman karasal) olarak sınıflandırılmakta ve bu geçiş iklimi iklerini yansıtmaktadır (Şekil 6).



Şekil 6. Bingöl ilinin Köppen ve Köppen-Trewartha İndeksine göre görünüşü (MGM, 2024)

3.3 ETCCDI Tabanlı Aşırı İklim Göstergeleri

CSDI (Soğuk Dönem Süresi): Kış aylarında sık soğuk hava dalgaları.

FD0 (Don Günleri): Yılda ortalama 100 gün, minimum sıcaklık 0°C altındadır.

GSL (Vejetasyon Dönemi Uzunluğu): Ortalama 180 gündür.

ID0 (Buz Günleri): Maksimum sıcaklığın 0°C'nin altında olduğu günler.

SU25 (Yaz Günleri): Yaz aylarında 25°C'nin üzerinde 60–80 gün.

TN10p / TN90p: Sıcak gecelerde artış gözlenmektedir.

TR20: Tropikal gece nadirdir.

TX10p / TX90p: Sıcak günlerde belirgin artış.

TXn / TXx: Yıllık uç sıcaklıklar -15°C ile 41°C arasında değişmektedir.

CDD (Art Arda Kurak Günler): Son yıllarda yaz kuraklığı artış göstermiştir.

CWD (Art Arda Yağışlı Günler): İlkbahar aylarında yağış kümelenmeleri belirgindir.

DTR (Günlük Sıcaklık Farkı): Yüksek; 10–16°C arası.

PRCPTOT: Ortalama yıllık yağış 830 mm'dir.

R10mm / R20mm: İlkbaharda 10 mm ve 20 mm üzeri yağışlı günler artış göstermiştir.

R95p / R99p: Aşırı yağış olayları daha sık hale gelmiştir.

RX1day / RX5day: Maksimum tek gün ve 5 günlük yağışlar 45 mm'ye kadar ulaşabilmektedir.

4. Sonuç

Hesaplanan indis değerleri Çizelge 1'de gösterilmektedir. Çizelge incelendiğinde Bu kapsamlı değerlendirme, Bingöl ilinin yarı kurak ile yarı nemli iklim rejimleri arasında geçiş özellikleri taşıdığını ortaya koymaktadır. Klasik iklim indeksleri uzun vadeli desenleri öne çıkarırken, ETCCDI göstergeleri kısa vadeli aşırı olayların şiddetlendiğini göstermektedir. Yaz kuraklıkları, sıcak günlerin artışı ve ilkbahar yağışlarının yoğunlaşması; bölgesel düzeyde entegre iklim uyum planlaması ve risk yönetimi gerektiren başlıca bulgulardır.

İndis	Başlangıç Yılı	Bitiş Yılı	Eğim Tahmini	Olasılık Değeri
CSDI	2000	2022	-0,116	0,042
FD0	2000	2022	-0,22	0,069
GSL	2000	2022	0,298	0,061
ID0	2000	2022	-0,06	0,71
SU25	2000	2022	0,224	0,003
TN10p	2000	2022	-0,061	0,039
TN90p	2000	2022	0,141	0,042
TR20	2000	2022	0,2	0,001
TX10p	2000	2022	-0,041	0,031
TX90p	2000	2022	0,101	0,011
TXn	2000	2022	0,011	0,611
TXx	2000	2022	-0,005	0,381
WSDI	2000	2022	Hesaplanamadı	
CDD	2000	2022	-0,047	0,598
CSDI	2000	2022	-0,132	0,041
CWD	2000	2022	-0,009	0,714
DTR	2000	2022	0,001	0,401
PRCPTOT	2000	2022	-0,791	0,523
R10mm	2000	2022	-0,011	0,602
R20mm	2000	2022	-0,006	0,657
R25mm	2000	2022	Hesaplanamadı	
R95p	2000	2022	-0,298	0,709

5. Öneriler

Yerel yönetimler, bölgesel planlama ve erken uyarı sistemlerinde klasik indekslerle birlikte ETCCDI göstergelerini de entegre etmelidir. Yaz kuraklıklarının etkisini azaltmak için modern sulama altyapıları önceliklendirilmelidir. İklim izleme ağları, ETCCDI analizlerini gerçek zamanlı yapabilecek şekilde genişletilmelidir. Bingöl'e özgü iklim kırılganlıklarını gösteren risk haritaları geliştirilmelidir.

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EVALUATIONS ON THE RELATIONSHIP BETWEEN PRECIPITATION AND AGRICULTURAL YIELD

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ABSTRACT

Precipitation is one of the key determinants of agricultural productivity, playing a critical role not only in the sustainable management of water resources but also in maintaining ecosystem balance. The agricultural sector is highly sensitive to variations in the amount, timing, and distribution of rainfall. In recent years, fluctuations in precipitation patterns due to global climate change have led to significant uncertainties in crop yields, soil moisture imbalances, and increased agricultural vulnerability. This study evaluates the impact of changes in precipitation regimes on agricultural production in Turkey, with a particular focus on the Eastern Anatolia Region. Additionally, the effects of climate change on food security are discussed, along with recommendations for adaptive agricultural strategies.

Keywords: Precipitation Regime, Agricultural Yield, Climate Change, Food Security, Rural Resilience

YAĞIŞ – ÜRÜN İLİŞKİSİ ÜZERİNE DEĞERLENDİRMELER

ÖZET

Yağış, tarımsal üretimin temel belirleyicilerinden biri olarak hem su kaynaklarının sürdürülebilir yönetimi hem de ekosistem sağlığı açısından kritik bir rol üstlenmektedir. Tarım sektörü, yağış miktarındaki, dağılımındaki ve zamanlamasındaki değişimlere son derece duyarlıdır. Küresel iklim değişikliğiyle birlikte, son yıllarda yağış rejimlerinde görülen belirsizlikler; ürün veriminde dalgalanmalara, toprak nemi dengesizliklerine ve artan tarımsal risklere yol açmaktadır. Bu çalışmada, Türkiye genelinde ve özellikle Doğu Anadolu Bölgesi özelinde yağış rejimindeki değişimlerin tarımsal üretime olan etkileri değerlendirilmiştir. Ayrıca, iklim değişikliğinin gıda güvenliği üzerindeki yansımaları ile alternatif üretim stratejileri üzerine öneriler sunulmuştur. Yağış rejiminin değişmesi ürün çeşitliliğini de doğrudan etkilemektedir.

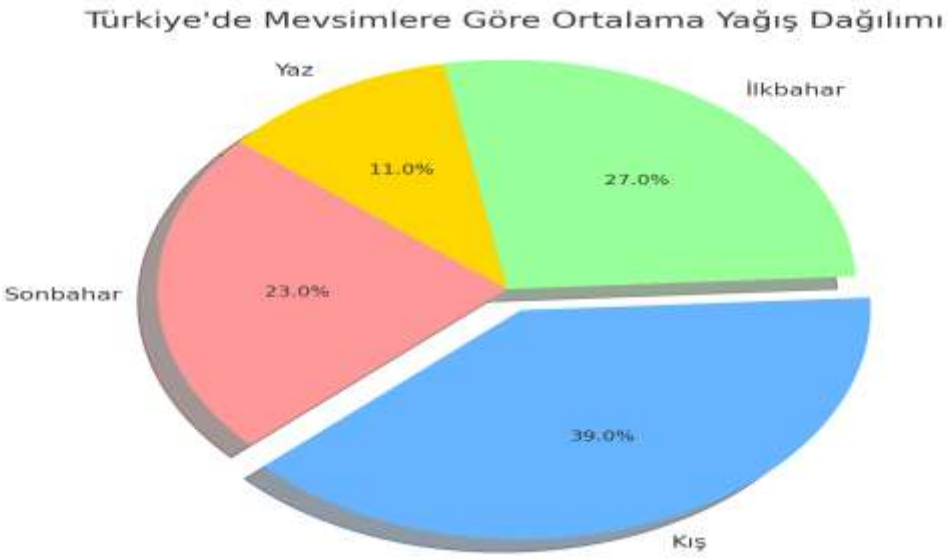
Anahtar Kelimeler: Yağış Rejimi, Tarımsal Üretim, İklim Değişikliği, Gıda Güvenliği, Kırsal Dirençlilik

1. Giriş

Tarımsal üretim sistemlerinin sürdürülebilirliği, büyük oranda doğal kaynaklara, özellikle suya bağımlıdır. Su döngüsünün temel bileşenlerinden biri olan yağış, ekosistemlerin düzenli işleyişini sağladığı gibi tarımsal faaliyetlerin zamanlamasını ve verimliliğini de doğrudan etkilemektedir. Ancak son yıllarda gözlemlenen düzensiz yağış rejimleri, tarım alanlarında kuraklık, aşırı nemlilik, toprak erozyonu gibi olumsuz etkiler yaratmakta; bu durum üretim planlaması açısından öngörülemezliğe neden olmaktadır. Yağış sürekli olarak değişmekte ve bu değişime karşılık üretim planları da değişmeye zorlanmaktadır. Son yıllarda küresel anlamda değişen iklim özellikle Akdeniz'e kıyısı olan ülkelerde çok daha derinden hissedilmeye başlamıştır. Türkiye iklim değişikliğini en derinden hisseden Akdeniz ülkelerinin başına gelmektedir. İklim değişmektedir. Bu kaçınılmaz bir gerçek olarak karşımızda durmaktadır. Ancak bu gerçeği görmezden gelemeyeceğimiz gibi oturum ağıt yamanında bir faydası olmayacaktır. Aksine yeni alternatifler üretmek, doğayı korumak ve ekolojik dengeyi sürdürülebilir sekle sokmak gerekmektedir.

2. Türkiye'de Yağış Rejimini Belirleyen Faktörler

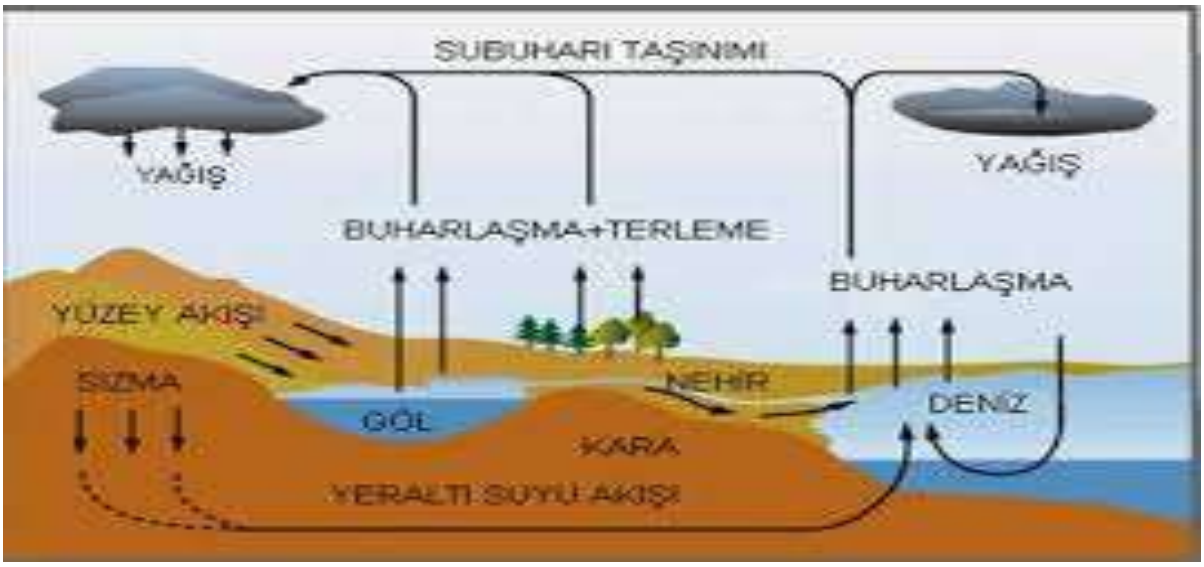
Türkiye'nin yağış rejimi; çeşitli atmosferik ve topografik faktörlerin bileşimiyle şekillenmektedir. Başlıca belirleyiciler arasında Hava Kütleleri ve Cephe Hareketleri: Karadeniz ve Akdeniz'den gelen nemli hava kütlelerinin Anadolu'nun iç kesimlerinde etkisini kaybetmesi, iç bölgelerdeki kuraklığı artırmaktadır. Topografya: Yükselti, eğim ve bakı gibi faktörler yağış miktarını ve türünü doğrudan etkiler. Karasallık: İç bölgelerde deniz etkisinin azalması, mevsimsel sıcaklık ve nem farklarını artırmakta ve yağışların düzensizleşmesine neden olmaktadır. Fizyografik Unsurlar: Ormanlık alanlar, göller ve tarım alanlarının dağılımı da mikroklimatik yağış farklılıklarına yol açmaktadır. Yağış rejiminin dağılımı şekil 1'de gösterilmektedir.



Şekil 1. Türkiye'de Mevsimlere Göre Ortalama Yağış Dağılımı

Şekil incelendiğinde en yüksek yağışın kış aylarında olduğu görülmektedir. Bunu ilk bahar ve sonbahar ayları izlemektedir. Ancak yağan yağışların miktarlarında düşme ile rejimsel olarak ciddi sorunlar yaşanmaktadır. Örneğin yaz ayları boyunca 150 mm yağış alan bölgelerde bu miktar bir gün içinde yağabilmektedir. Taşkın, sel ve toprak kayması gibi olumsuzluklar yaşanabilmektedir. Yapış rejimini belirleyen faktörlerde son yıllarda değişimler olmaya

başlamıştır. Bu değişimler ile iklimin tarımsal üretime olumsuz etkisi artmaya başlamıştır. Şekil 2'de yapış rejiminin belirleyicileri gösterilmektedir.



Şekil 2. Yapış rejiminin belirleyicileri

Bazen çok yağan ve bazen de hiç yağmama durumları strese sebep olmaktadır. Bunun sonucunda ise bitkiler strese girmekte verim ve kalite kayıpları baş göstermektedir. Yağış rejimini şekillendiren orman miktarının belirgin şekilde azalması, göllerin kurumaya başlaması ve kentleşme ile yol yapımları ciddi olarak rejimin değişmesini etkilemektedirler.

3. Yağış Rejimi ve Tarımsal Üretim

Yapış rejimindeki düzensizlik öncelikle bitkisel ve hayvansal üretimi etkilemektedir. Ürün deseninde gözlenen değişimler ile birlikte hayvanların besin maddesi temini bakımından yeterli yem üretiminin sağlanamaması sonucu ile karşılaşılmaktadır. Yağışın hem mevsimsel hem de yıllık dağılımındaki düzensizlikler;

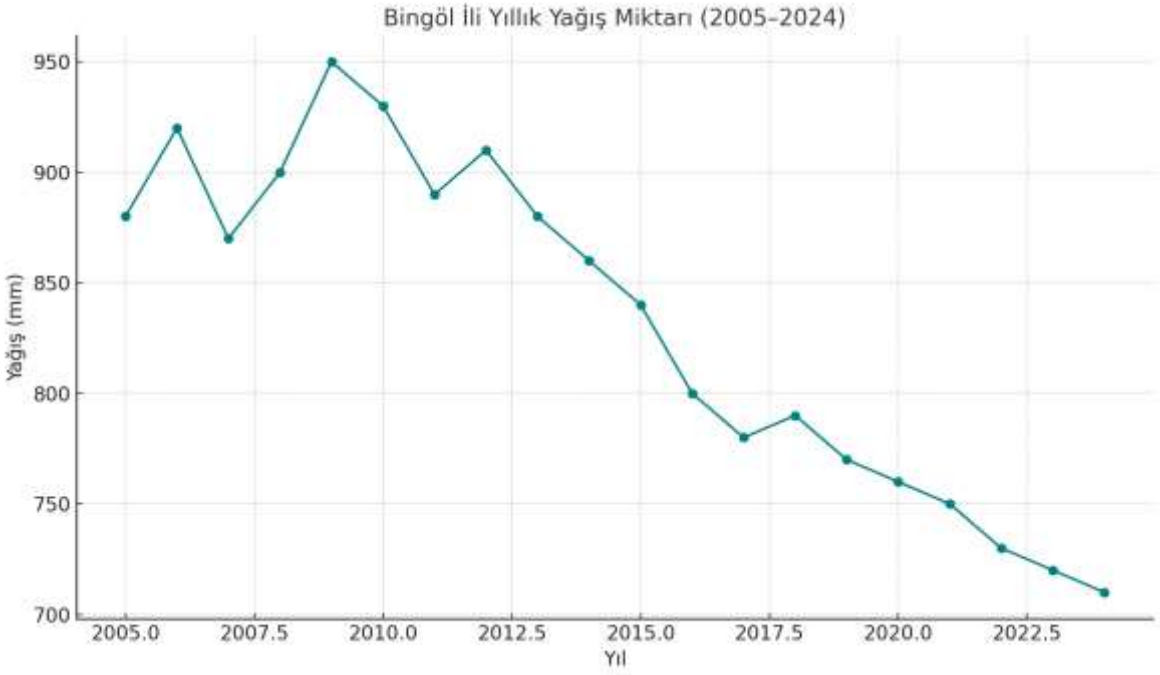
- Ekili alanların gelişim evrelerinde kritik su yetersizliklerine,
- Hasat dönemlerinde aşırı yağışa bağlı kalite kayıplarına,
- Verin ve kalite kayıplarına,
- Yemlerdeki kalite düşüklüğü ile birlikte hayvansal ürünlerdeki kalite düşüklüğüne,
- Tohum çimlenmesi ve fide gelişiminde gecikmelere yol açmaktadır.

Özellikle kuraklık stresine duyarlı ürünlerde (ör. buğday, mercimek gibi) verim kayıpları daha belirgin olmaktadır. Ayrıca yaz aylarında artan sıcaklıklarla birlikte yağış azlığı, sulama ihtiyacını artırmakta ve yer altı su kaynakları üzerinde baskı oluşturmaktadır.

4. Doğu Anadolu Bölgesi Örneği

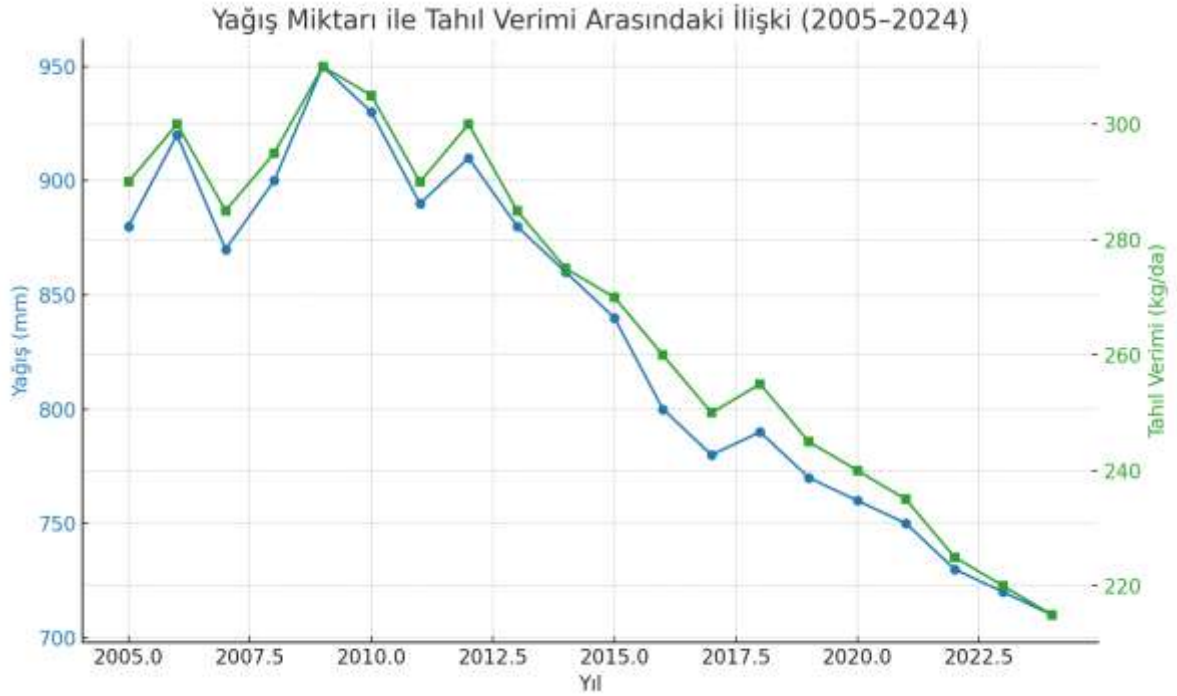
Doğu Anadolu Bölgesi, yüksek rakımı ve karasal iklim özellikleriyle Türkiye'nin diğer bölgelerinden ayrılmaktadır. Yıllık yağış miktarı bazı alanlarda yeterli gibi görünse de, bu yağışların düzensiz zamanlaması (örneğin çiçeklenme ya da hasat dönemlerinde yoğunlaşması), ürün verimini olumsuz etkilemektedir. Ayrıca son yıllarda kış yağışlarında az Doğu Anadolu'da son 20 yılda yağışlar azalma eğilimi göstermektedir. Yapışların son 20 yıldaki durumunun gösteren grafik Şekil 3'de gösterilmektedir. Şekil incelendiğinde yağış

miktarının gelecek açısından belirgin şekilde azaldığı görülmektedir. Eğer gerekli tedbirler alınmazsa geleceğin iyi olmayacağı söylenebilir.



Şekil 3. Bingöl İli Yıllık Yağış Trendi (2005–2024)

Bitkisel üretim denilince her zaman için akla ilk gelen tahıllar olmaktadır. Tahıllar bizler için temel besin kaynağımız olan un ve ekmeğin ana kaynağı olduğundan önemli olmaktadır. Yağış miktarı azaldıkça verim ve kalitede düşmeye başlamıştır. Şekil 4'de yağış miktarı ile tahıl verimi arasındaki ilişki gösterilmektedir. Şekil incelendiğinde 2015 yılından itibaren düşüsün ciddileştiği ve geriye dönme hareketi yapmadığı görülmektedir. Bu aslında bizlere bir uyardır. Eğer gerekli tedbirler alınmazsa ciddi sorunlar ile karşılaşmak kaçınılmaz olacaktır. Verim azalması aynı zamanda birim alandan alınacak olan ürün miktarının da azalması anlamına gelmektedir. Birim alandaki azalma ise rekolteye olumsuz etki yapacaktır. Ülke olarak yıllık 20 milyon ton buğdaya ihtiyacımız bulunmaktadır. Ancak son yıllarda üretim miktarı azaldığından 16 milyon tona kadar düşmüştür. Bu nedenle de dışarıdan buğday ithali başlamıştır. Kuraklığın ve iklim değişiminin dünyanın her yerini etkilediği düşünüldüğünde ileride paramız olsa bile alım yapmayacağımız akıldan çıkarılmamalıdır. Bunun için fazla gecikilmeden üretim planlamaları ve uygun ürün desenlemesi çalışmalarının yapılması gerekmektedir.



Şekil 4. Yapış Miktarı le Tahıl Verimi Arasındaki İlişki

5. İklim Değişikliği ve Gıda Güvenliği

İklim değişikliğinin etkileri sadece tarımsal üretimle sınırlı kalmamakta; aynı zamanda gıda tedarik zinciri, fiyat dalgalanmaları ve besin erişimi gibi temel gıda güvenliği bileşenlerini de tehdit etmektedir. Gıda güvenliği şu dört temel unsurla değerlendirilmelidir:

1. Gıdanın Tedariki (availability): Gıdanın tedariki her yıl bir önceki yıla göre zorlaşmaktadır. Bu nedenle daha ciddi davranılmalı ve gıda tedariki konusunda erkenden tedbirler alınmalıdır. Hatırlanacağı gibi pandemi döneminde parayla dahi ürün alınamamıştır.

2. Gıdaya Erişim (accessibility): Gıdaya erişimde tedarike bağlı olarak değişmektedir. Tedarik yapılamayınca erişimde zorlaşmaktadır.

3. Gıdanın Kullanılabilirliği (utilization): Bazı durumlarda ise gıdaya ulaşılsa da gıda maddesinin kullanılabilir olmadığı görülebilmektedir. Kalitesiz gıda aynı zamanda sağlığı da tehdit edebilecektir.

4. Gıda Sistemlerinin İstikrarı (stability): İstikrar her yerde öncelikli olmalıdır. İstikrarlı olan yerler her aman için güven veren yerlerdir. Gıda sistemlerinin istikrarı da bizlere gelecek açısından güven vermelidir.

Yağış rejimindeki öngörülemezlik, bu dört temel alanı da zayıflatarak kırılgan grupların (çiftçiler, düşük gelirli tüketiciler) üzerindeki baskıyı artırmaktadır.

6. Sonuç ve Öneriler

Tarımsal üretimin iklim değişikliğine karşı dayanıklılığını artırmak için;

- Kuraklığa ve strese dayanıklı türlerin yaygınlaştırılması,

- Yerel hava ve toprak verilerine dayalı erken uyarı sistemlerinin kurulması,
- Çiftçilerin iklim riskleri konusunda bilinçlendirilmesi,
- Sulama teknolojilerinin modernize edilmesi gibi önlemler öncelikli olmalıdır.
- Ayrıca, iklim-tarım senaryolarına dayalı üretim planlamalarının desteklenmesi ve bölgesel politikaların oluşturulması büyük önem taşımaktadır.

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RESEARCH ON TURKISH GRAPEVINE GENETIC RESOURCES AND A LOCAL EXAMPLE FROM ERZİNCAN, CV. KARAERİK

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ABSTRACT

Türkiye is recognized as a significant center of genetic diversity for grapevine (*Vitis vinifera* L.) owing to its strategic geographical location and varied climate. The extensive viticultural activities practiced across the country for millennia have facilitated the development of numerous indigenous varieties and types. While traditional variety identification has been based on ampelographic characteristics, the application of molecular techniques in determining grape varieties has become increasingly prevalent due to the susceptibility of ampelographic traits to environmental conditions and vine age. Türkiye's rich grapevine genetic resources face the threat of extinction due to environmental factors, the prevalence of diseases and pests, a decline in demand for local varieties, and socio-economic transformations. Projects aimed at the conservation of grapevine genetic resources are of paramount national importance for safeguarding both production and heritage against potential future adversities. Furthermore, the promotion of locally cultivated grape varieties, an increase in the number of scientific publications focusing on these varieties, the support of adaptation studies in diverse viticultural regions, and the fostering of their perception as a millennia-old natural heritage are crucial for establishing sustainability in viticulture and ensuring the effective conservation of existing genetic resources. These strategies will significantly contribute to the economic valorization of local varieties, enhance the motivation of farmers to preserve and cultivate these varieties, and consequently mitigate genetic erosion. This study synthesizes significant research conducted on grapevine genetic resources and evaluates the current status of these resources within Türkiye, with a specific focus on the Karaerik grape variety, which holds socio-economic and cultural significance for the Erzincan region.

Keywords: Grapevine, genetic resource, Karaerik

Introduction

Grapes, among the myriad fruits generously provided by nature, distinguish themselves through their unique attributes. This assertion might initially appear ambitious; however, those who delve into the origins, evolutionary trajectory, rich diversity, and distinguished position of this ancient fruit among other global fruits can readily discern that these words are not an exaggeration but rather an expression of profound admiration for the grape (Anlı, 2006). Numerous exceptional qualities set grapes apart from other fruits. Acting as a vibrant living palette or an artist leaving its mark wherever it touches, the grape stands as one of the Earth's most prolific fruits. Throughout history, it has transcended its role as a fundamental food source and a sweet delicacy; both the fruit itself and its derived products have become an indispensable component of diverse cultures (Anlı, 2006). Indeed, the history of this ancient fruit is as old as human history itself, and it has consistently held a significant position in Anatolia (Doğan, 1996). Archaeological evidence suggests that the domestication process of *Vitis vinifera* commenced approximately 6000 to 7000 years ago in Southeastern Anatolia (the Asian part of Türkiye) or Transcaucasia, from where it disseminated via various routes to neighboring regions in Europe and North Africa (McGovern, 2003; Zohary et al., 2012), (Figure 1).

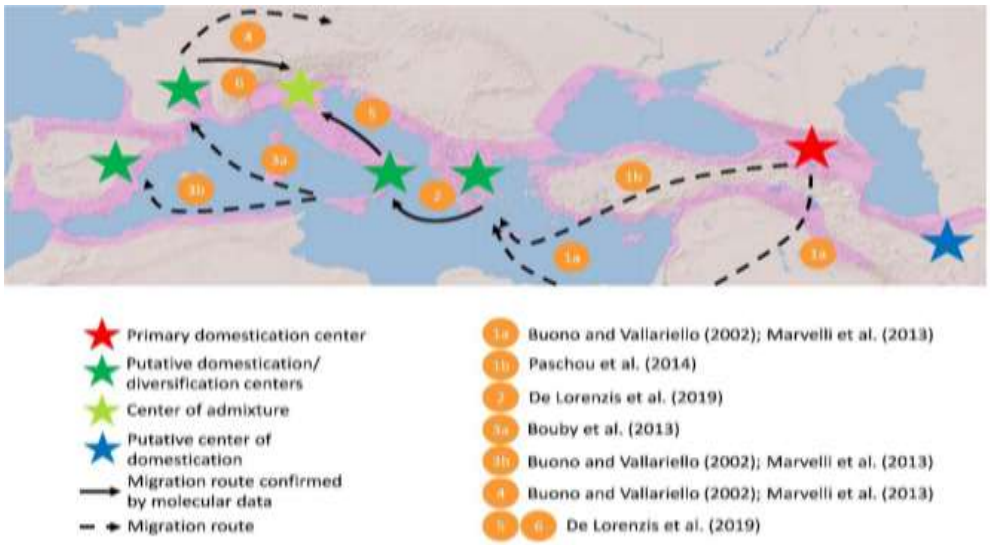


Figure 1. Possible migration and domestication route of grapevine (Grassi & De Lorensiz, 2021).

While the distribution areas of grapevine are generally limited to regions between 20°-52° north and 20°-40° south latitudes, grape cultivation can also be feasible in high-altitude areas near the equator in both the southern and northern hemispheres (Sağlam & Sağlam, 2018). Notably, the 35°-45° north latitude belts in the northern hemisphere stand out as zones where vineyard areas are concentrated. Türkiye's geographical location between the 36°-42° north latitude lines indicates that the country's geography is highly suitable for viticulture (Odabaş, 1980; Özden & Vardin, 2009). Furthermore, Türkiye is situated at the intersection of the Anatolian and Near Eastern gene centers, serving not only as a significant gene source for the world's important fruit species and varieties (İlim Serhat et al., 2017) but also lying within the world's most favorable climatic zone for viticulture (Taşkesenlioğlu et al., 2022). Research findings

corroborate that Türkiye is among the key gene centers for cultivated grapevine (*Vitis vinifera* L. *sativa*) and wild grapevine (*Vitis vinifera* spp. *sylvestris*) (Arroyo Garcia et al., 2006).

The discovery of grape-related shapes and reliefs in historical artifacts unearthed during archaeological excavations in various regions of Türkiye serves as a significant indication of the deep-rooted history of viticultural culture in these areas. Indeed, notable findings pertaining to viticulture from prehistoric periods have been encountered in excavations conducted across the country. For instance, archaeological work in Yozgat Alişar revealed a wine and beverage vessel in the form of a grape cluster, dating back to 1800-1600 BCE. Similarly, gold wine goblets and wine jugs dating to 2300 BCE were found in the royal tombs of Çorum Alacahöyük. Furthermore, grape motifs, wine vessels, and amphorae are frequently observed on ancient coins minted in settlements where viticulture flourished in the Aegean and Marmara regions (Çelik, 2011).Thanks to its cultural accumulation and favorable climate for viticulture, Türkiye ranked 7th in global grape production in 2023, with 3,400,000.00 tons of grapes produced on 377,848 hectares of land (FAO, 2024).

The cultivated grapevine (*Vitis vinifera* L. subsp. *sativa*) is widely grown globally and has evolved from the wild grapevine (*Vitis vinifera* L. subsp. *sylvestris* Gmel.) through millennia of natural or artificial hybridization and selection processes (Oraman, 1972; This et al., 2006). Southern Caucasus, the western Caspian Sea region, and Anatolia stand out as regions with the highest natural genetic diversity of grapevine. Türkiye is recognized as a significant gene center for both cultivated (*Vitis vinifera* L. *sativa*) and wild (*Vitis vinifera* spp. *sylvestris*) grapevine (ArroyoGarcia et al., 2006). Globally, approximately 10,000 grape varieties are reported to exist (Alleweldt, 1997). The high genetic diversity among *Vitis* species has been shaped by factors such as the sexual reproduction mechanism and spontaneous mutations (Vouillamoz & Grando, 2006; Myles et al., 2011; Margaryan et al., 2021). According to the Vitis International Variety Catalogue over 12,000 grapevine varieties have been recorded. (Maul & Töpfer, 2015). However, the number of economically cultivated varieties is limited, with producers predominantly favoring commercial varieties (Bouby et al., 2013). The rapid spread of the phylloxera epidemic has led to a significant reduction in grapevine genetic diversity. Additionally, the removal of old and local varieties with less desirable traits from vineyards over time has been another crucial factor contributing to the depletion of genetic resources (Tello et al., 2019; Kaya et al., 2023). The diversity observed in contemporary grapevine populations is a result of a protracted evolutionary process intertwined with human influence. Vavilov (1951) posited that the geographical regions where plants are cultivated should be the primary consideration in determining their origin. According to this approach, the region exhibiting the highest level of diversity for a plant species indicates its gene center, or place of origin (Fidan, 1985; Karataş & Karataş, 2018). For a long time, humankind primarily regarded soil, water, and air as fundamental natural resources; however, genetic resources have recently been included in this list. One of the elements that makes our planet unique within the solar system is its wealth of genetic resources. Genetic resources encompass the genetic material (genes) that directs the development of living organisms. The conservation of genetic resources is not a novel concept. For instance, the practices of collecting and storing seeds for the subsequent production cycle have a history as old as written records (Yalçın Dittgen, 2023).

The intersection of three of the world's seven major biogeographical regions (Mediterranean, Euro-Siberian, and Irano-Turanian) (Figure 2) renders Türkiye a remarkably rich country in terms of plant biological diversity (Muminjanov & Karagöz, 2019). Efforts towards the collection of plant genetic resources in Türkiye and the evaluation of their potential gained momentum in the early 20th century. Turkish scientist Mirza Gökgöl, during a period when the

global significance of genetic resources was not yet fully comprehended, contemporaneously with leading scientists of the era such as Vavilov, Harlan, and Zhukovsky, meticulously examined plant samples he collected from various regions of Türkiye in 1929, 1930, 1935, and 1939 (İşçi & Altındişli, 2023).

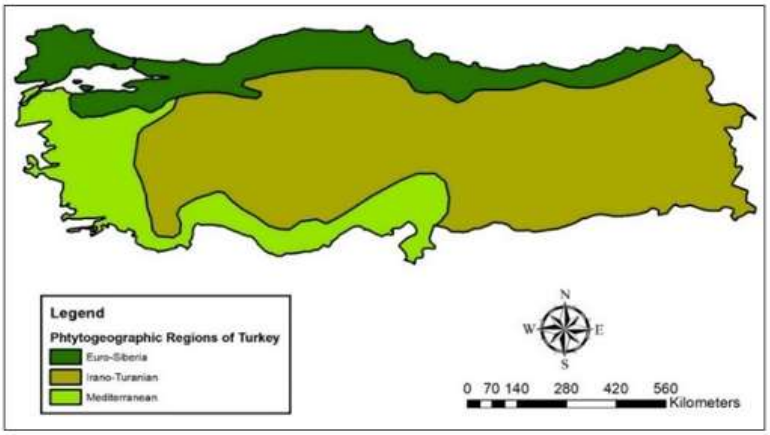


Figure 2. Three biogeographic regions in Türkiye (Aktürk & Güney, 2021)

The sustainability and advancement of viticulture, which holds a significant position within Turkish agriculture, are contingent upon the effective identification and conservation of the country's rich grapevine (*Vitis vinifera* L.) genetic resources. Türkiye possesses a remarkable genetic diversity in terms of the number of grapevine varieties and types. Traditionally, the diagnosis of these varieties has primarily relied on ampelographic characteristics (leaf, cluster, berry morphology, etc.) (Tekdal & Sarlar, 2016).

In Türkiye, the initial ampelographic studies aimed at the scientific identification of grapevine (*Vitis vinifera* L.) varieties were initiated in 1926 by Ahmet Hamdi. Ahmet Hamdi examined the viticulture of Ankara Province and the ampelographic characteristics of the grape varieties cultivated in this region, adhering to Moog's (1930) methodology (Çelik & Karanis, 1998). The fundamental criteria accepted for determining the ampelographic characteristics of grapevine include: the shoot tip type, the morphology of young and mature leaves, the characteristics of shoots and one-year-old branches, the color and pubescence status of organs, as well as the characteristics of the inflorescence, berry, and seed (Moog, 1930; Fidan et al., 1996).

Numerous valuable studies have been conducted in Türkiye in the field of ampelography. In another of the early ampelographic works, Oraman (1937) meticulously examined the viticulture of Ankara province and shared his findings in his publication titled "Viticulture of Ankara Province and the Ampelography of the Main Grape Varieties Grown in Ankara." This study holds the distinction of being the first scientific publication on ampelography in Türkiye. Kısakürek (1950) addressed the viticulture of the Southeastern Anatolia Region, describing the ampelographic characteristics of 27 distinct grape varieties and identifying their potential synonyms. Pamir (1956) investigated the viticulture of the Marmara Region, providing the ampelographic characterization of 21 commonly cultivated grape varieties in the area. İştar (1959), on the other hand, focused on the viticulture of the Mediterranean Region, specifically researching the vineyards of İçel (Mersin) and identifying 19 standard grape varieties in this region. In subsequent years, ampelographic studies intensified in various regions. Fidan I. and Fidan Y. (1976) investigated the viticulture of the Gülnar district, identifying 48 distinct grape

varieties and providing detailed ampelographic descriptions for 21 of them. Yalınkılıç (1996) examined the viticulture of Kahramanmaraş province, determining the ampelographic characteristics of 23 white and 10 colored grape varieties cultivated in the region. Ecevit and Kelen (1999), in their study on the viticulture of Isparta Province, ascertained that all varieties in the region belonged to the *Vitis vinifera* L. species. Kader and Ilgın (2002) investigated the phenological development of 5 seedless and 4 seeded grape varieties, introduced from the United States and France, in the collection vineyard of the Manisa Viticulture Research Institute. Odabaş et al. (2002) and Köse et al. (2004) determined the ampelographic characteristics of the Dişi Mercan, Erkek Mercan, Abalıkoca, Horoz Yüreği, Merzifon Karası, Amasyalık, Kırmızı Üzüm, and Kazova grape varieties grown in Amasya province, confirming that all these varieties belong to the *Vitis vinifera* L. species (Tekdal & Sarlar, 2016).

The most comprehensive initiative for the systematic collection and conservation of Türkiye's grapevine genetic resources is the project titled "Identification, Conservation, and Characterization of Turkish Grapevine Genetic Resources," launched in 1965 by the Tekirdağ Viticulture Research Institute, affiliated with the Ministry of Agriculture and Forestry of the Republic of Türkiye (İşçi & Altındişli, 2023). This project marked a significant milestone with the aim of securing the country's viticultural potential and genetic richness. Through this project, the National Collection Vineyard (field gene bank) currently located in Tekirdağ (Figure 3) conserves the largest number of grapevine genetic resources in the country, encompassing a total of 1539 accessions, including 1439 local types and 104 accessions of foreign origin, across a 90-decare area. In addition to the Tekirdağ Viticulture Research Institute, various levels of responsibility for the conservation of grapevine genetic resources are undertaken by field gene banks of some other institutes affiliated with the Ministry of Agriculture and Forestry (Table 1). For example, the Manisa Viticulture Research Institute conserves 1231 grapevine genetic resources, while the Pistachio Research Institute in Gaziantep maintains 112 accessions (Aykas et al., 2018).



Figure 3. National Collection Vineyard (Tekirdağ)

Table 1. Institutes Responsible for Grapevine Genetic Resources

Institute	Responsibility
Pistachio Research Institute, Gaziantep	Responsible for conservation at the regional level.
East Mediterranean Transitional Zone Agricultural Research of Institute, Kahramanmaraş	Responsible for conservation at the regional level.
Horticultural Research Institute, Erzincan	Responsible for conservation at the regional level.
Apricot Research Institute, Malatya	Responsible for conservation at the regional level
Viticulture Research Institute, Manisa	Responsible from conservation at second degree.
Viticulture Research Institute, Tekirdağ	Responsible from conservation at first degree.

In addition to the Viticulture Research Institutes, five other Research Institutes engaged in viticultural activities are also establishing their collections by conducting surveys within their respective areas of responsibility. As a result of the work carried out by these research institutes, the "Catalogue of Turkish Grapevine Genetic Resources," comprising photographs, inventory, and ampelographic information of 883 genotypes, was published in 2012 (Anonymous, 2021). Characterization information is available for 62% of the fruit and grapevine genetic material conserved in *ex situ* gene banks in Türkiye. When Turkish field gene banks are examined according to fruit groups, grapes rank first with a proportion of 28% (Aykas et al., 2018).

***Vitis vinifera* L. cv. Karaerik**

The Erzincan Plain is a prominent region in Türkiye in terms of plant biological diversity, and within this richness, the Karaerik grape variety has consistently held a central position in local grape production due to its superior fruit characteristics (Küpe et al., 2021). The indigenous Karaerik (Cimin) variety, which constitutes approximately 99% of the vineyards in Erzincan, has been cultivated using unchanged traditional methods since 800 BCE. Having developed a high degree of adaptation to the unique soil and climatic conditions of Erzincan, this variety requires fewer inputs (pesticides, fertilizers, etc.) compared to other grapes, thus presenting a sustainable production alternative (Taşkesenlioğlu et al., 2022).

Karaerik, a variety of *Vitis vinifera* L., holds the distinction of being the first variety registered as a "Registered Geographical Indication" under the name "Cimin üzümü" in the Turkish Patent Institute's list, with registration number 37 and dated June 13, 2001. It is particularly cultivated intensively in the Üzümlü (Cimin) district of Erzincan. Characterized by black, oblate-oval berries, Karaerik has an average berry weight of 3-4 grams, a seed count ranging from 1 to 4, medium skin thickness, firm berry density within the cluster, and an average cluster weight of 300-500 grams (Ekinci, 2008), (Figure 4). A distinctive bloom is present on the surface of its berries. The flavor profile exhibits a delicate balance between tart and sweet, accompanied by a unique aroma not found in other grape varieties (Karadeniz & Altınbilek, 2016).

The training system employed for the Karaerik grape variety is the baran system, a cultivation method unique to the region (Figure 4). The baran system is a distinctive growing technique where the grapevine trunk is buried underground, with its branches left above the soil surface, and the soil is mounded in a fishbone pattern. Due to its characteristic appearance and aroma, Karaerik grapes are in high demand in Erzincan city center and surrounding provinces. The harvest period extends from the beginning of September to the end of October (Köse & Güleryüz, 2009; Küpe, 2012, Özoğul & Küpe 2025). The number of individuals who do not

engage in viticulture or do not have grapes in their gardens is quite low in the district center and some villages. A significant portion of the produced grapes is consumed fresh, while a certain amount is used to make products such as molasses and fruit pulp. Furthermore, it is known that a substantial quantity of a local product called "saruç" is produced, although not officially recorded. Saruç is made by halving Karaerik grapes, placing walnuts in between, and then stringing them on a thread like prayer beads (Özoğul, 2024).

In 2024, 5488 tons of Karaerik grapes were produced in Erzincan across an area of 9279 decares (TÜİK, 2024).



Figure 4. Karaerik grape (left) and baran training system (right)

Conclusion

The identification and conservation of grapevine genetic resources are of critical importance for the advancement of viticulture, a significant component of Turkish agriculture. Local varieties, facing the risk of extinction due to ecological changes, improper cultivation practices, the proliferation of harmful organisms, and the insufficient maintenance of vineyard areas resulting from labor shortages caused by rural-to-urban migration, must be protected by their inclusion in genetic resource collections. Grapevine genetic resources, which encompass living materials harboring genes with current and future potential value for humanity, include propagation materials such as seeds, pollen, DNA, and vegetative material used in the conservation and multiplication of plant genetic diversity. Therefore, genetic resources hold strategic importance for sustainable viticulture. Ensuring the food and nutritional security of the present and future, safeguarding this genetic richness, a heritage of millennia, and transmitting it to future generations is a vital necessity. Particularly, ensuring the sustainability and conservation as genetic resources of unique varieties grown in limited geographical areas and adapted to local conditions can establish a crucial safeguard mechanism for the continuity of agricultural production against the unpredictable adverse effects of global climate change.

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Aronia melanocarpa: A PROMINENT FRUIT WITHIN THE BERRY FAMILY

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ABSTRACT

The escalating global population and the concurrent reduction in arable land are generating considerable challenges concerning food accessibility. Simultaneously, the increasing prevalence of health-related issues underscores the critical need for nutritious diets. Within this context, *Aronia melanocarpa* emerges as a promising fruit for both agricultural producers and consumers alike. Its adaptability to a wide range of climatic and soil conditions, coupled with its precocious fruit-bearing habit, ease of cultivation, and abundant content of polyphenols, minerals, and vitamins, positions it as an advantageous crop. Furthermore, its potential applications extend beyond fresh consumption into the cosmetic, pharmaceutical, and food processing sectors, suggesting a trajectory of increasing *Aronia melanocarpa* production in the years to come. A thorough investigation into the role of *Aronia melanocarpa* products and by-products in human nutrition and their contributions to overall well-being is therefore of paramount importance. Current scientific literature supports the premise that *Aronia melanocarpa*, characterized by its multifaceted functions and health-promoting attributes, holds substantial potential as a valuable component of a nutritious and health-conscious dietary regimen. This study endeavors to elucidate the positive attributes of *Aronia melanocarpa* from both horticultural and health perspectives, thereby aiming to enhance its recognition and public awareness.

Keywords: Aronia, berries, chokoberry, miracle fruit

Introduction

Due to its geographical location and diverse climatic characteristics, Turkey possesses a rich potential for various fruit species. Among these fruits, berry fruits have been experiencing increasing consumer interest both globally and within Turkey in recent years. While berry fruits are generally consumed fresh, their processing potential contributes to their growing significance in the industrial sector (Engin & Boz, 2018). The increasing production of berry fruits is significantly influenced by their positive effects on human health. Owing to their high levels of anthocyanins and phenolic compounds, berry fruits exhibit potent antioxidant properties. This enhances their importance in a balanced diet and their potential to protect the body against various oxidative stress factors, thereby contributing to their growing popularity (Tosun & Yüksel, 2003). Furthermore, the presence of minerals, which are essential for the healthy functioning and development of human physiology, is a well-established fact. The rich mineral content of berry fruits is also noteworthy in this context. Adequate consumption of berry fruits aids in the relaxation of the human body and the replenishment of lost minerals (Ağaoğlu, 2003). Among these berry fruits, aronia has recently become the most prominent, with rapidly increasing production and consumption volumes. Aronia (*Aronia melanocarpa*) is a species native to the eastern regions of North America and Canada, and it was introduced to Europe and Russia via return migrations in the late 19th century, subsequently being domesticated (Hardin, 1973; Strigl et al., 1995). Belonging to the Rosaceae family, aronia flowers in May, and its fruits are harvested between August and September. This long-lived berry fruit species, with an average lifespan of 15 to 20 years, develops in a shrub form and can reach heights of 2 to 3 meters Initially regarded solely as an ornamental plant, the cultivation of *Aronia melanocarpa* has gradually become widespread with the discovery of its resistance to low-temperature conditions (-30°C) and the superior health benefits of its fruits(Ara, 2002). This study closely examines *Aronia melanocarpa*, which has gained significant global demand in recent years due to its positive effects on human health and whose cultivation area is steadily increasing, with the aim of contributing to its recognition.

Systematics and Varieties of Aronia

Order: Rosales,

Family: Rosaceae,

Genus: Aronia

The three most well-known *Aronia* species are red-fruited (*Aronia arbutifolia* (L.) Elliot), purple-fruited (*Aronia prunifolia* (Marsh)), and black-fruited (*Aronia melanocarpa* (Michx) Elliot) But the most common and well-known of these three varieties is *Aronia melanocarpa*. (Hardin, 1973; Lehmann, 1982; Jeppsson, 2000). *Aronia melanocarpa*, introduced to the European continent in the early twentieth century, has been domesticated over time, leading to the development of standardized cultivars such as 'Albigowa', 'Ahonnen', 'Aron', 'Autumn Magic', 'Dabrowice', 'Egerta', 'Fertödi', 'Galicjanka', 'Hakkija', 'Hugin', 'Kurkumachki', 'Kutno', 'McKenzie', 'Morton', 'N', 'Nero', 'Nova', 'Rubin', 'Serina', 'Viking', and 'Wies' (Sidor & Gramza-Michałowska, 2019). Its suitability for mechanical harvesting, resistance to transportation processes, and storage potential contribute to this plant species being increasingly preferred by farmers.

Botanical Characteristics of Aronia

Aronia melanocarpa is a perennial shrub species native to North America. Typically reaching a height of 80 to 140 cm, its berries are approximately 6 mm in diameter and turn purplish-

black upon ripening. The plant's leaves, ranging from 3 to 7 cm in length, have a glossy and glabrous (hairless) surface. Its white-pink flowers bloom in May (Hardin, 1973; Scott & Skirvin, 2007). The flowers of *Aronia* are hermaphroditic, with 20 to 25 flowers arranged in a corymb (Figure 1). An average of 8 to 14 fruits develop from these flowers. The floral structure exhibits typical characteristics of the Rosaceae family, including 5 sepals, 5 petals, and a variable number of stamens (male reproductive organs) ranging from 10 to 30. The flowering period lasts approximately 20 to 25 days. *Aronia melanocarpa* is a self-fertile species and does not require a pollinator plant for fertilization (Poyraz & Engin, 2018).



Figure 1. Fruit and flowering period of Aronia

Climatic Requirements

While *Aronia melanocarpa* does not have specific climate requirements, temperate climate zones offer optimal growing conditions. Its high tolerance to frost enables its cultivation across a wide geographical range globally. This plant species exhibits significant resistance to low temperatures, and since its flowering occurs around May, after the risk of late spring frosts, the flowers and young fruits are protected from frost damage. Cultivation in areas with good sun exposure is particularly critical for productivity and fruit quality. Direct sunlight exposure on the fruits increases their sweetness, while shaded fruits tend to have a more pronounced tannic structure. Shoots under snow cover can withstand low temperatures down to -30 to -35°C. However, flower damage can occur if the temperature drops to -2.3°C during the flowering period (Anonymous, 2021; Kadıoğlu & Yılmaz, 2023).

Soil Requirements

Aronia melanocarpa is a perennial, shrub-forming berry fruit species with a high degree of adaptability, enabling its cultivation in various soil types and across a broad pH range. For optimal growth, well-drained, medium-textured soils rich in organic matter and with a pH value between 6.0 and 6.5 are recommended. The presence of organic matter not only supplies essential nutrients and moisture to the soil but also improves aeration and drainage, thereby creating favorable conditions for plant development (Trinklein, 2007; Hannan, 2013; Fidancı, 2015).

Water Requirements

The water requirement of *Aronia melanocarpa* is similar to that of many other fruit species. An annual rainfall of 500 to 600 mm is generally sufficient for plant development; however, the

distribution of rainfall, particularly during the vegetation period, is crucial. Water stress, which can negatively impact yield, typically occurs during dry periods in July and August, coinciding with the rapid fruit growth stage. Irrigation practices can be implemented using either drip irrigation or sprinkler systems, taking into account available resources and land conditions (Trinklein, 2007; Hannan, 2013; Fidancı, 2015).

Harvest and Yield

The fruits of *Aronia melanocarpa* develop in clusters, with each cluster typically containing 5 to 15 berries. The fruit ripening period varies between 90 and 110 days, depending on cultivar characteristics, the type of branch left after pruning techniques, and regional climatic conditions. Harvesting takes place when the fruits ripen, usually in late August or early September. During the ripening process, the berries exhibit softening, increased color intensity, sweetening, and an increase in berry size. However, fruits harvested before reaching full maturity have lower quality compared to those that ripen naturally on the shoots. *Aronia melanocarpa* berries can be harvested manually or using mechanical harvesting equipment (Figure 2). In the United States and Europe, aronia harvesting is commonly done with specialized machines similar in design to blueberry harvesters. At full yield capacity, an average of 10 kg of fruit per plant and 2 tons per hectare can be obtained from *Aronia* (Table 1), (Anonymous, 2021).

Table 1. Yield of *Aronia melanocarpa* by year

Year	kg/tree	kg/da
4	5	1000
5	6	1200
6-10	8	1600
11-15	10	2000
16-19	10	2000
20	10	2000



Figure 2. Hand (left) and machine harvesting (right) of aronia

Aronia in the World

Aronia, utilized for centuries by Native Americans for disease resistance (Moerman, 1998), naturally occurs in the Great Lakes region of northeastern North America and in the higher-elevation foothills and wetlands of the Appalachian Mountains to the south (Rossell & Kesgen, 2003). In 1910, in Russia, Ivan Mitschurin initiated breeding programs to obtain sweet-fruited varieties of North American *Aronia* species by hybridizing them with *Sorbus* and *Mespilus* species. These efforts resulted in the development of two distinct cultivars: 'Likernaja' and 'Desertnaja Michurina'. Following World War II, starting in 1946, *Aronia* cultivation began to spread across Europe and Russia (Walther & Müller, 2012). In the 1980s, *Aronia* cultivation commenced in Scandinavian countries such as Denmark and Finland, as well as in former Soviet Bloc countries including Bulgaria, Czechoslovakia, East Germany, Poland, and Slovenia (Walther & Müller, 2012). Poland accounts for approximately 90% of global aronia production. The United States (2500 tons) and Germany (1434 tons) follow Poland in production volume (Table 2). Commonly cultivated aronia varieties in different countries include 'Aron' in Denmark, 'Nero' in the Czech Republic, 'Viking' in Finland, 'Hugin' in Sweden, 'Fertödi' in Hungary, and 'Nero' and 'Viking' in Turkey (Strigl et al., 1995; Šnebergrová et al., 2014; Fidancı, 2015).

Table 2. Aronia production of some countries (Şahin & Erdoğan, 2022)

Country	Production Area (ha)	Production Quantity (tons)
Poland	6000	50000
USA	800	2500
Germany	583	1434
Türkiye	78	130
Finland	60	4

Aronia in Türkiye

Despite being a relatively new fruit species in Türkiye, aronia cultivation has been rapidly increasing in recent years. The initial studies on aronia in Türkiye were conducted in Yalova in 2012, followed by the establishment of the first orchards in 2014. Kırklareli currently ranks first in Turkey in terms of aronia production area, followed by Bursa and Manisa (Table 3).

Table 3. Aronia Production Area of Türkiye

Provinces	Trees(pieces)	Production Area (da)
Kırklareli	40.000	240
Bursa	23.500	141
Manisa	15.500	90
Kırşehir	8.000	48
Yalova	8.000	48
Çanakkale	7.000	42
Samsun	6.000	36
İzmir	5.000	30
Antalya	3.000	18
İstanbul	3.000	18
Ordu	3.000	18
Ankara	2.000	12

Aronia for Health

Aronia contains various bioactive components such as carbohydrates, organic acids, amino acids, minerals, vitamins, aroma compounds, and polyphenols (Kulling & Rawel, 2008). The chemical composition of *Aronia* fruit is influenced by various factors, including climatic conditions, soil structure, fruit maturity level, harvesting techniques, and storage conditions. Notably, its high polyphenol content distinguishes it significantly from other fruits (Tolić et al., 2017). Polyphenols are fundamental compounds that impart characteristic taste, aroma, color, nutritional value, and antioxidant properties to fruits (Robards et al., 1999). In recent years, polyphenols have garnered significant attention as promising candidates in the prevention of cardiovascular diseases. *Aronia melanocarpa* has garnered significant interest due to its exceptionally high polyphenol content, including anthocyanins and caffeic acid derivatives, and exhibits a wide range of health-promoting effects (Górska-Drabik et al., 2023; Bloch, 2025). Antioxidants play a critical role in safeguarding human health through their capacity to neutralize free radicals and prevent cellular damage. Consequently, antioxidant effects hold significant potential in alleviating conditions triggered by oxidative stress, such as cancer, infections, cardiovascular diseases, and diabetes. Within this framework, the phenolic compounds and other natural products found in high concentrations in aronia fruits, which exhibit potent antioxidant activity, contribute to the improvement of human health (Ren et al., 2022; Negreanu-Pirjol et al., 2023).

Due to its diverse bioactive components, vitamins, minerals, and particularly its high content of polyphenolic compounds, *Aronia melanocarpa* (chokeberry) and its leaves offer a broad spectrum of health benefits (Jurikova et al., 2017; Szopa et al., 2017). The primary polyphenolic constituents of *Aronia melanocarpa* possess potent antioxidant capacities, as well as anti-inflammatory, anticancer, antimicrobial, antiviral, antidiabetic, antiatherosclerotic, hypotensive, antiplatelet, and anti-inflammatory properties (Borowska & Brzóska, 2016; Kulling & Rawel, 2008; Jurikova et al., 2017; Szopa et al., 2017). Furthermore, polyphenols

are known to play a preventive role in the development of cancer and heart diseases (Oszmiański & Wojdyło, 2005; Jelska et al., 2024). Given the concentrated and consistent composition of bioactive compounds in standardized *Aronia* extract, which may not be present in sufficient amounts in *Aronia* juice and other preserves, its consideration for cardiovascular health is highly significant. The Oxygen Radical Absorbance Capacity (ORAC) value of aronia berries indicates that they possess the highest antioxidant capacity among the fruits and berries investigated to date (Figure 3), (Wang & Cao 1996; Kalt et al., 1999; Ehlenfeldt et al., 2001; Wang & Strecth., 2001; Moyer et al., 2002; Wu XL et al., 2004; Jakobek L et al., 2004).

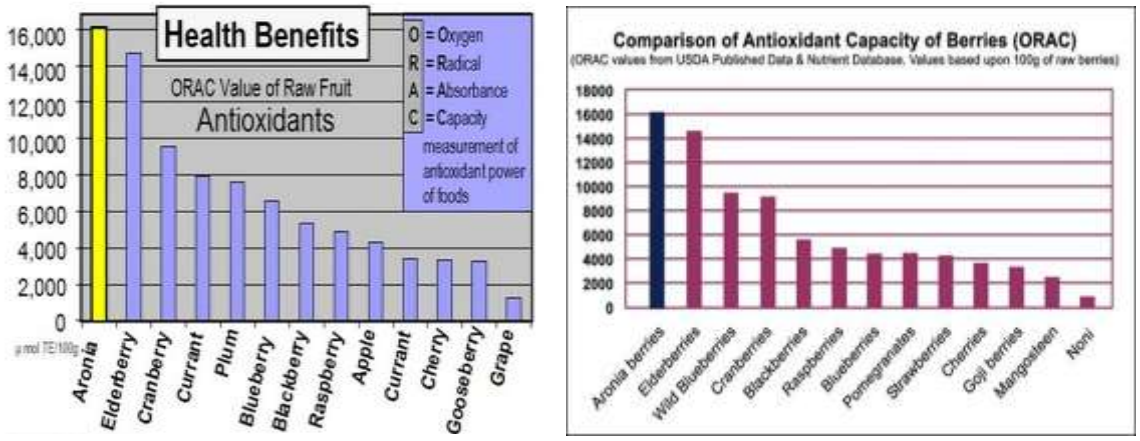


Figure 3. Antioxidant capacity, measured as ORAC, of various fresh berries and fruits including chokeberries

Usage Areas

Aronia berries have a wide range of applications, including fresh consumption, the fruit juice industry (consumed alone or as a cocktail with other fruit juices), the pharmaceutical industry (using dried fruit, flowers, roots, and leaves), dairy technology (aronia-flavored ice cream and milk), dried fruit technology (in fruit bread, buns, cakes, puddings, and pastries), the spice industry, fruit salads, jam, marmalade, and the canning industry, tea production (using dried leaves and dried fruit), and dietary menus. In breakfasts, aronia sauce or salsa can be used to add a distinctive taste and flavor to garnishes. Tea can be prepared from both the berries and the fresh leaves. Furthermore, aronia is a valuable fruit in the cosmetic industry, utilized in creams, soaps, skincare products, and as a raw material for fragrances. As a significant component of the Mediterranean diet, aronia is exceptionally rich in vitamins, minerals, and fiber (Figure 4), (Anonymous, 2021).



Figure 4. Some products of Aronia

Conclusion

The high adaptability of *Aronia* to diverse climatic and soil conditions, its early fruit-bearing characteristic (starting the year after planting), minimal cultural requirements, and favorable market value facilitate the expansion of its cultivation both globally and in Turkey. Its late flowering period, extending to the end of May, and long harvest season ensure fruit production even in regions prone to frost. The combination of its suitability for processing, rich bioactive content, and economic returns is driving increasing global interest in *Aronia*. Recognized for its positive effects on cancer, cardiovascular diseases, obesity, diabetes, and neurological disorders due to its high antioxidant content, aronia is gaining popularity as a "miracle fruit" in line with alternative medicine and natural nutrition trends. Consequently, it has become a sought-after fruit in the market for individuals seeking healthy foods, leading to a significant increase in its consumption. As the importance and health benefits of aronia are increasingly understood in Turkey, where its production and consumption are expanding daily, a rise in its use as fresh produce, dried fruit, and an additive in the food industry is anticipated.

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EVALUATING THE POTENTIAL OF LAVENDER AS BEE PASTURE

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ABSTRACT

Lavender (*Lavandula* spp.) is a semi-shrub and perennial plant with an economic life span of approximately 15 years. Especially its flowers and the essential oil obtained from them are commercially valuable. It is an important plant with analgesic, sedative, diuretic and anti-rheumatic properties, widely used in perfumery, cosmetics, pharmaceuticals, beekeeping and aromatherapy sectors, whose oil is at the forefront of the world essential oil trade. In its cultivation; it is a very important plant because it adapts to barren lands and requires low input costs (water, fertilizer), is important in terms of rural tourism with its visual richness during the flowering period and contributes to both local and national economy by offering new job opportunities. It is a plant that can be easily grown in most regions of our country in terms of its flowering between May and August, its resistance to drought, heat and cold. In addition to the above-mentioned advantages of lavender cultivation, it has the quality of being used as bee pasture due to its adaptability to climate and soil conditions, preference by bees, flowering period, life span, etc. In some regions, it is seen that lavender honey is among the preferred products among visitors due to the fact that beekeeping is also practiced in lavender gardens used for tourism purposes. Since lavender is a medicinal and aromatic plant, bees fed from lavender gardens are likely to gain resistance against diseases and pests. Producers who practice beekeeping close to lavender gardens offer alternatives to utilize lavender products to increase bee health and welfare in the hive.

As a result, the ease of lavender cultivation and the wide range of uses of its products, the economization of barren areas, the possibility of creating an additional source of income as bee pasture, and the possibility of being beneficial in bee welfare and health in the hive clearly show that lavender has an important potential as a bee pasture.

Key words: *Lavandula* spp., beekeeping, nutrition, essential oil, cultivation

LAVANTANIN ARI MERASI OLARAK KULLANILMA POTANSİYELİNİN DEĞERLENDİRİLMESİ

ÖZET

Lavanta (*Lavandula* spp.), yaklaşık olarak 15 yıllık ekonomik ömre sahip, yarı çalımsı ve çok yıllık bir bitkidir. Özellikle çiçekleri ve bunlardan elde edilen uçucu yağı ticari açıdan değerlidir. Dünya ucu yağ ticaretinde, yağı ön sıralarda yer alan, parfümeri, kozmetik, ilaç, arıcılık ve aromaterapi sektörlerinde yaygın kullanılan, analjezik, sedatif, diüretik ve anti-romatizmal özellikleri bulunan önemli bir bitkidir. Yetiştiriciliğinde; kıraç arazilere uyum sağlaması ve düşük girdi maliyetleri (su, gübre) gerektirmesi, çiçeklenme dönemindeki görsel zenginlik ile kırsal turizm açısından önemli, yeni iş olanakları sunması ile hem yerel hem de ulusal ekonomiye katkı sağlamasında dolayı oldukça önemli bir bitkidir. Mayıs -Ağustos ayları arasındaki çiçeklenmesi, kuraklığa, sıcak ve soğuğa dayanıklılığı bakımından ülkemizin çoğu bölgesinde kolaylıkla yetiştirilebilen bir bitkidir. Lavanta yetiştiriciliğinin yukarıda belirtilen avantajlarının yanında özelikle iklim ve toprak koşullarını uyumu, arılar tarafından tercih edilmesi, çiçeklenme periyodu, ömür uzunluğu vb. sebeplerden dolayı arı merası olarak kullanılma niteliği taşımaktadır. Bazı bölgelerde turizm amaçlı kullanılan lavanta bahçelerinde aynı zamanda arıcılık yapılması ile ziyaretçiler arasında lavanta balının en fazla tercih edilen ürünler arasında olduğu görülmektedir. Lavantanın tıbbı ve aromatik bir bitki olması nedeni ile lavanta bahçelerinden beslenen arıların hastalık ve zararlılara karşı direnç kazanma olasılıkları yüksektir. Lavanta bahçelerine yakın arıcılık yapan üreticilerin kovan içi arı sağlığı ve refahını artırmada lavanta ürünlerinden yararlanma alternatifleri sunmaktadır.

Sonuç olarak lavanta yetiştiriciliğinin kolaylığı ve ürünlerinin geniş kullanım alanına sahip olması, kıraç alanların ekonomiye kazandırılması, arı merası olarak ek gelir kaynağı oluşturması, kovan içi arı refahı ve sağlığında faydalı olma olasılığı lavantanın arı merası olarak önemli bir potansiyele sahip olduğunu açıkça göstermektedir.

Anahtar kelimeler: *Lavandula* spp., arıcılık, beslenme, uçucu yağ, yetiştiricilik

Giriş

Günümüzde hızla artan insan nüfusu, teknolojik gelişmeler ve değişen yaşam koşulları doğal kaynaklar üzerindeki baskıyı her geçen gün artırmaktadır. Doğal döngülerin insan müdahalesiyle bozulması, su, toprak ve bitki örtüsü gibi yaşamsal kaynakların giderek azalmasına ve ekosistemlerin dengesinin sarsılmasına yol açmaktadır. Bu durum yalnızca çevresel sorunları değil aynı zamanda gıda güvenliği ve sürdürülebilir tarımsal üretimi açısından da ciddi tehditler oluşturmaktadır (Sancak et al., 2013). Özellikle son yıllarda yaşanan küresel salgınlar ve iklim değişikliği tarımsal üretimin ve doğal kaynakların korunmasının ne denli hayati olduğunu bir kez daha gözler önüne sermiştir.

Bitkisel ve hayvansal üretim insan sağlığının ve yaşam kalitesinin temelini oluştururken bu iki alan arasındaki etkileşim sürdürülebilir tarımın başarısı için kritik öneme sahiptir. Tarımsal üretimde yalnızca ana ürün verimine odaklanmak yerine bitkilerin yan faydalarının ve atıklarının da değerlendirilmesi, entegre tarım uygulamalarının yaygınlaştırılması gerekmektedir. Özellikle arıcılık, hem ekosistem hizmetleri hem de ekonomik getirisiyle bu döngüde merkezi bir rol üstlenmektedir. Arılar bitkilerin tozlaşmasında üstlendikleri vazgeçilmez görevleri sayesinde hem doğal ekosistemlerin hem de tarımsal alanların biyolojik çeşitliliğinin korunmasına katkı sağlamaktadırlar (Balfour et al., 2013). Dünya genelinde tarımsal üretimin yaklaşık üçte biri arıların gerçekleştirdiği tozlaşmaya bağlı olup bu durumun arı popülasyonlarının sağlığının gıda güvenliği açısından ne kadar kritik olduğunu göstermektedir (Chu & Kemper, 2001). Türkiye sahip olduğu zengin bitki çeşitliliği, farklı iklim ve topografik özellikleriyle arıcılık açısından büyük bir potansiyele sahiptir (Avcı, 1993; Kumova & Korkmaz, 2000). Ülkemizde hem doğal vejetasyonda hem de kültürel tarımda kullanılan çok sayıda bitki türü, arıların beslenmesi ve arı ürünlerinin kalitesi açısından önemli fırsatlar sunmaktadır. Ancak mevcut potansiyelin tam anlamıyla değerlendirilebilmesi için arı merası olarak kullanılabilecek bitki türlerinin çeşitlendirilmesi ve sürdürülebilir tarım uygulamalarının yaygınlaştırılması gerekmektedir (Genç, 1990; Doğaroğlu & Genç, 1995). Arıların sağlıklı ve verimli bir şekilde faaliyet gösterebilmesi için kaliteli ve çeşitli arı meralarına ihtiyaç duyulmaktadır. Ancak geleneksel arı meralarının azalması, tarımsal monokültürlerin yaygınlaşması ve doğal vejetasyonun tahrip edilmesi arıların besin kaynaklarında ciddi daralmalara yol açmıştır. Bu nedenle alternatif ve sürdürülebilir arı merası bitkilerinin önemi giderek artmaktadır (Sorkun, 2008). Özellikle tıbbi ve aromatik bitkiler hem arıcılık hem de kırsal kalkınma açısından yeni fırsatlar sunmaktadır. Lavanta (*Lavandula* spp.) bu bitkiler arasında öne çıkmakta; uzun çiçeklenme dönemi, yüksek nektar ve polen verimi, kuraklığa dayanıklılığı ve farklı ekolojik koşullara uyum yeteneğiyle arıcılık için cazip bir seçenek oluşturmaktadır (Balfour et al., 2013). Lavanta tarlaları arılar için uzun süreli ve zengin bir besin kaynağı sunarken lavanta balı da kendine özgü aroması, yüksek antioksidan içeriği ve ekonomik değeriyle hem yerel hem de uluslararası pazarlarda ilgi görmektedir. Bunun yanı sıra lavanta yetiştiriciliği kırsal alanlarda ekonomik çeşitliliği artırmakta, istihdam olanakları yaratmakta ve sürdürülebilir kalkınma hedefleriyle uyumlu bir model sunmaktadır. Lavantanın endüstriyel ve tıbbi kullanımları da bu bitkinin stratejik önemini daha da pekiştirmektedir (Sancak et al., 2013; Balfour et al., 2013).

Bu çalışmada; lavantanın botanik özellikleri, ekolojik gereksinimleri, ekonomik ve endüstriyel önemi, arı merası olarak kullanımı, arıcılık ve bal kalitesi üzerine etkileri, lavanta balının özellikleri, lavanta ve arı sağlığı ilişkisi ile sürdürülebilir kalkınma ve kırsal turizm açısından önemi ele alınmıştır.

Lavantanın Botanik Özellikleri ve Yetiştiriciliği

Lavanta (*Lavandula* spp.) Ballıbabagiller (*Lamiaceae*) familyasına ait çok yıllık ve aromatik bir bitki olup, dünya genelinde 30'dan fazla türü bulunmaktadır. Ekonomik açıdan en önemli türleri *Lavandula angustifolia* (İngiliz lavantası), *Lavandula x intermedia* (lavandin), *Lavandula latifolia* (spike lavanta) ve *Lavandula stoechas* (İspanyol lavantası) olarak gösterilmektedir (Vairinhos & Miguel, 2020; Aprotosoaie et al., 2023). Yarı çalımsı özelikte olan lavanta; yaşlandıkça bitkinin alt kısımlarından başlayarak yukarıya doğru odunsu hale gelen çok sayıda dal gelişir. Bu dallar üzerinde karşılıklı sıralanmış 2 ile 6 cm uzunluğunda, oldukça kısa saplı ve gri-yeşil tonlarında yapraklar bulunur. Lavantanın yapraklarının her iki yüzeyi uçucu yağ içeren pamuksu tüylerle kaplıdır. Bitkinin çiçekleri 20-30 cm uzunluğundaki çıplak sapların uç kısmında bulunur. Çiçek başakları yaklaşık 15-20 cm uzunluğundadır. Her bir başakta ortalama 5 ila 6 çiçek kümesi yer alır ve bu kümelerin her birinde 5 ile 15 arasında çiçek bulunur. Lavantanın çiçekleri çok kısa saplı ve gri-mavi renklidir. Her bir çiçeğin iç yüzeyi parlak ve düz, dış yüzeyi ise tüylü olan yaklaşık 5 mm uzunluğunda çanak yapraklarla çevrilidir. Bu çanak yaprakların dış kenarlarında uçucu yağları depolayan, sapları tek hücreden oluşan çok sayıda küçük tüy bulunur. Lavanta küçük tohumlu bir bitki türüdür. Tohumları yaklaşık 2 mm uzunluğunda ve 1 mm enindedir. Uzunumsu oval şekilde olup rengi koyu ve parlak kahverengidir. Bulunduğu bölgenin iklimine bağlı olarak 80 ile 100 cm derinliğe kadar inebilen sağlam bir kazık kök sistemine sahiptir (Duarte & Souza, 2014; Giray, 2018; Pokajewicz et al., 2021; Pokajewicz et al., 2022).

Kökeni itibari ile Akdeniz iklim bitkisi olan lavanta, yetiştiriciliği başta Akdeniz ve Eğe bölgeleri olmak üzere son yıllarda ülkenin farklı yerlerinde talep gören bir bitki olmuştur. İlk tarımsal üretimi Isparta, Burdur ve Denizli illerinden yaygınlaştığı kabul edilmek ile birlikte özellikle Isparta ili ülke üretiminin %93'ünü karşılamaktadır (Güler & Korkmaz, 2018). Lavanta üretim maliyetlerinin düşük olması ve ihracatının uzun yıllar sorunsuz devam etmesi bu bitkinin ekonomik önemini artırmaktadır. Ancak son yıllarda bölge ülkelerinin pazara girmesiyle rekabet artmıştır.

Lavanta, sıcak iklimleri seven ve yüksek ısı ihtiyacı olan bir bitkidir. Ortalama 230-245 günlük gelişme sürecinde yaklaşık 3600 °C'lik bir sıcaklık toplamına gereksinim duyar. Soğuklara karşı da dirençlidir; çok yıllık gövdeleri -26 °C'ye kadar dayanabilir. Gelişim dönemi başından çiçek açımına kadar olan süreçte yağış bitkinin büyümesini desteklerken çiçeklenme döneminde ise sıcak, kuru ve güneşli hava koşulları uçucu yağ verimini artırır. Lavanta ışık seven bir bitki olup güney ve güneydoğuya bakan, bol güneş alan yamaçlarda daha iyi gelişim gösterir. Hafif yapılı, iyi havalanan, besin yönünden zengin ve genellikle kumlu, taşlı, alkali ya da nötr topraklarda sağlıklı gelişim gösterir. Asitli, ağır killi ve su tutan zeminlerde yetiştirilmeye uygun değildir. Topraktaki mevcut besin içeriğine göre gübreleme yapılır. Dallanmayı teşvik etmek için azot ilkbaharda verilir; fosfor ve potasyum ise sonbahar toprak işlemesi sırasında uygulanır. Lavanta hem tohumla hem de vejetatif yollarla (çelik, kök sürgünü vb.) çoğaltılabilir. Ancak tohumla çoğaltıldığında lavanta yabancı döllenmeye açık olduğu için ana bitkinin verim ve kalite özelliklerini kaybetme riski vardır. Çelikle çoğaltma daha uygun olup, çelikler sağlıklı ve bakımı yapılmış anaç bitkilerden genellikle Aralık-Şubat ayları arasında alınır. Fideler 1 yaşında iken sonbaharda genellikle Kasım-Aralık aylarında ve kırağı tehlikesi geçtikten sonra dikilmelidir. İlkbaharda dikim yapılacaksa, kuraklık başlamadan önce, Şubat-Mart aylarında gerçekleştirilmelidir. Lavanta, kuraklığa karşı dayanıklı bir bitkidir. Bu özelliği, derinlere inebilen güçlü kök sistemi ve yapraklarını kaplayan buharlaşmayı azaltıcı tüyler sayesinde kazanır. Sadece dikimin yapıldığı yıl yaz aylarında sulamaya ihtiyaç duyabilir. İlk yıl kök sistemi tam olarak gelişirse, sonraki yıllarda sulamaya gerek kalmaz. Ayrıca,

kuraklığa dayanıklı bir tür olması nedeniyle su kaynaklarının sınırlı olduğu bölgelerde de başarıyla yetiştirilebilir (Aprotosoaie et al., 2023). Lavanta dikildiği yıl çiçek verebilmekte bu nedenle Haziran, Temmuz ve Ağustos aylarında birkaç kez çiçek sürgünleri kesilerek bitkinin olumsuz etkilenmesi önerilir. 8. yılından sonra bitkide verim kayıplarını önlemek için gençleştirme budaması yapılır. Sıra aralarında ve bitki çevresinde hem mekanik hem de kimyasal yabancı ot mücadelesi yapılabilir. Hasat, elle ya da makineyle yapılabilir. En yüksek uçucu yağ verimi, bazı çeşitlerde çiçeklerin yarısı açtığında, bazılarında ise tam çiçeklenme sırasında elde edilir. Genellikle çiçeklenmenin %80'ine ulaşıldığında hasat gerçekleştirilir. Lavanta kuraklığa dayanıklı, kireçli ve iyi drene edilmiş topraklarda yetişebilme yeteneği, düşük su ihtiyacı ve hastalık-zararlılara karşı doğal direnci ile sürdürülebilir tarım uygulamaları için önemli bir alternatif tarımsal üründür (Aslancan & Sarıbaş, 2011; Katar et al., 2020). Bitkinin ömrü uygun bakım koşullarında 15-20 yıla kadar uzayabilmekte, fide ile çoğaltma yöntemiyle ekimden sonraki ikinci yıldan itibaren ekonomik verim alınabilmektedir. Ayrıca lavanta tarlalarının arıcılıkla entegre edilmesi hem bitki verimini hem de arı ürünlerinin kalitesini artırmaktadır (Tarhan et al., 2019).

2. Lavantanın Ekonomik ve Endüstriyel Önemi

Lavantanın ekonomik değeri; başta uçucu yağ olmak üzere kozmetik, ilaç, gıda ve turizm sektörlerinde yaygın kullanımından kaynaklanmaktadır. Lavanta ve lavandin uçucu yağları parfüm, farmasötik, kozmetik ve kişisel bakım ürünleri başta olmak üzere çok çeşitli endüstriyel alanlarda geniş bir kullanım yelpazesine sahiptir (Cavanagh & Wilkinson, 2002; Lesage-Meessen et al., 2015). Lavanta yağı içeriği ve kalitesi; tür, genotip, çevresel koşullar, agronomik uygulamalar ve işleme-depolama süreçlerine bağlı olarak değişkenlik göstermektedir (Mantovani et al., 2013; Golubkina et al., 2020). Lavanta yağı, antiinflamatuar (Hajhashemi et al., 2003; Cardia et al., 2018), antioksidan (Biesiada et al., 2008; Carrasco et al., 2016), antibakteriyel ve antimikrobiyal (Tardugno et al., 2018) gibi çeşitli biyoaktif özelliklere sahip olup aynı zamanda doğal ve güvenli bir herbisit olarak da değerlendirilmektedir (Ibanez, 2019). Tarihsel olarak lavanta uçucu yağı bedensel ve ruhsal arınma, uykusuzluk, kaygı, yorgunluk, sindirim sorunları, saç dökülmesi, baş ve diş ağrısı gibi pek çok rahatsızlığın giderilmesinde kullanıla gelmiştir (Sienkiewicz et al., 2011; Soltani et al., 2013; Gül et al., 2016; Stanev et al., 2016; Karakaya & Ceylan, 2023). Ayrıca lavanta yağı, antimikrobiyal özellikleri nedeniyle gıda koruyucu olarak da değerlendirilmektedir (Lis-Balchin, 2023). Lavandula angustifolia (İngiliz lavantası) yüksek kaliteli uçucu yağ üretimiyle öne çıkarken, Lavandula x intermedia (lavandin) ise daha yüksek yağ verimiyle ve dünya genelinde en fazla üretilen lavanta yağı olmasıyla dikkat çekmektedir. Lavander yağı, lavandin yağına kıyasla daha yüksek kaliteye sahip olup, pazarda yaklaşık 2–5 kat daha yüksek fiyatlarla satılmaktadır. Lavanta uçucu yağı, başta linalool ve linalil asetat olmak üzere, 1,8-sineol, ocimene, terpen ve kafur gibi monoterpenlerden oluşmaktadır. Linalool ve linalil asetat oranları özellikle L. angustifolia, L. x intermedia ve L. latifolia türlerinde yüksek olup, bu bileşikler lavanta yağının ticari değerini belirleyen ana unsurlardır (Aprotosoaie et al., 2017; Karık et al., 2017; Vairinhos & Miguel, 2020; Aprotosoaie et al., 2023). Uluslararası Standartlar Organizasyonu (ISO) ve çeşitli farmakopeler, lavanta uçucu yağında linalool ve linalil asetatın dengeli oranlarda bulunmasını ve kafur ile 1,8-sineol gibi bileşiklerin düşük seviyelerde olmasını kalite kriteri olarak belirlemiştir. Lavandin yağında ise kafur ve 1,8-sineol oranları daha yüksektir (ISO 8902:2009). Küresel ölçekte lavanta ve lavandin yağları, özellikle Avrupa pazarında büyük talep görmekte olup, ABD ve Asya pazarlarında da son yıllarda artan bir ilgi söz konusudur. 2018 yılında kozmetik sektörünün küresel hacmi 420 milyar dolara ulaşırken,

uçucu yağ ticaretinin değeri 5,44 milyar dolar olarak kaydedilmiştir. Dünya lavanta yağı üretiminde Bulgaristan ve Fransa başı çekmekte, bu iki ülke toplam üretimin üçte ikisini karşılamaktadır (Giray, 2018; Stanev et al., 2016; Koba et al., 2018). Lavandin yağı üretiminin ise %90'ı Fransa'da gerçekleştirilmektedir (Lesage-Meessen et al., 2015). Türkiye'de özellikle Isparta-Keçiborlu-Kuyucak bölgesi, lavanta üretimi ve lavanta turizmi açısından öne çıkmaktadır (Tarhan et al., 2019). Lavanta balı ise, yüksek piyasa değeri ve özgün aroması ile arıcılık sektöründe önemli bir yer tutmaktadır. Ayrıca lavanta, kırsal kalkınma ve kadın istihdamı açısından da önemli fırsatlar sunmaktadır (Tarhan et al., 2019). Lavanta yağı, dünya genelinde en çok ticareti yapılan uçucu yağlardan biridir. Kozmetik ve parfümeri sektöründe yaygın olarak kullanılmakta ayrıca sabun, şampuan, krem ve losyon gibi ürünlerin üretiminde de tercih edilmektedir. Lavanta yağı, antimikrobiyal, antifungal ve antioksidan özellikleriyle de dikkat çekmektedir (Chu & Kemper, 2001). Türkiye'de lavanta üretimi, özellikle son on yılda artış göstermiş ve lavanta tarlaları, kırsal turizmin gelişmesine de katkı sağlamıştır (Tarhan et al., 2019).

Lavanta ve Arıcılık İlişkisi

Arı merası, arıların nektar ve polen toplamak için kullandığı bitki topluluklarını ifade eder. Arı meralarının zenginliği ve sürekliliği, arı kolonilerinin sağlığı ve bal verimi açısından kritik öneme sahiptir. Lavanta tarlaları arı kolonilerinin gelişimi ve bal üretimi açısından önemli avantajlar sunar. Lavanta; iklim ve toprak koşullarına dayanıklılığı, bakım işlerinin kolaylığı, uzun çiçeklenme süresi, yüksek nektar verimi, arı sağlığı ve refahına katkısı, biyoçeşitliliğe katkısı, ek gelir sağlaması vb. faydalarından dolayı arı merası olarak yüksek potansiyele sahip bir bitki türüdür. Lavanta çiçeklerinin yüksek nektar içeriği, arıların enerji ihtiyacını karşılamada önemli bir kaynaktır. Ayrıca lavanta uçucu yağlarının arı sağlığı üzerinde olumlu etkileri olduğu, bazı parazit ve hastalıklara karşı koruyucu rol oynayabileceği bildirilmektedir (Chu & Kemper, 2001). Özellikle lavanta çiçeklerinin yoğun olduğu bölgelerde arıların koloni gelişimi ve bal verimi artmaktadır (Balfour et al., 2013). Lavanta, arıların beslenme sürekliliğini sağlayan uzun çiçeklenme dönemiyle, arı kolonilerinin yıl boyunca yeterli nektar ve polen bulmasına olanak tanır. Bu durum, özellikle ilkbahar ve yaz aylarında arıların koloni gelişimi ve bal üretimi açısından büyük avantaj sağlar (Aslancan & Sarıbaş. 2011). Lavantanın çiçeklenme süresi, arı sayısı ve arının çiçekte kalma süresi bakımından önemli bir arı merası bitkisi potansiyelindedir (Uçar, 2022). Lavanta balı; açık sarıdan kehribar rengine kadar değişen rengi, kendine özgü aroması ve yüksek antioksidan içeriği ile diğer ballardan ayrılmaktadır. Piyasa değeri diğer monofloral ballara göre daha yüksektir. Lavanta balı antimikrobiyal ve antiinflamatuar özellikler taşımakta, yüksek oranda flavonoid ve fenolik bileşikler içermektedir (Chu & Kemper, 2001). Çiçeklenme döneminde yoğun nektar salgılaması nedeniyle arılar için önemli bir besin kaynağıdır. Lavanta arıcılık faaliyetleri için ideal ortamlar sunmakta, lavanta balı kendine has aroması ve antioksidan içeriğiyle dikkat çekmektedir (Seraj et al., 2023). Lavanta balı özellikle Fransa ve İspanya gibi ülkelerde yüksek ticari değere sahip olup ülkemizde son yıllarda önem kazanmaya başlamıştır. Lavanta uçucu yağlarının, arıların bağışıklık sistemini güçlendirdiği ve bazı zararlılara karşı koruyucu etkiler göstermektedir. Özellikle *Varroa destructor* gibi parazitlere karşı lavanta yağının potansiyel biyolojik mücadele ajanı olarak kullanılma potansiyeline sahiptir (Balfour et al., 2013). Lavanta uçucu yağlarının arıların bağışıklık sistemini güçlendirdiği, bazı zararlılara karşı koruyucu etkiler gösterdiği ve kovan hijyenini artırdığı bildirilmiştir (Chu & Kemper, 2001).

Lavantanın Sürdürülebilir Kalkınma ve Kırsal Turizm Etkileri

Lavanta tarımı; kırsal kalkınma ve sürdürülebilir tarım uygulamaları açısından önemli fırsatlar sunmaktadır. Lavanta tarımı ve arıcılığın entegrasyonu; kadın istihdamı ve kırsal turizmde

artışa yol açmış, arıcılık ve bal üretiminin yanı sıra, lavanta turizmi ile bölgesel ekonomiye katkı sağlamıştır (Tarhan et al., 2019). Lavanta tarlaları, fotoğrafçılık, doğa yürüyüşleri ve bal tadım etkinlikleriyle turizme entegre edilmiştir. Kırsal alanlarda lavanta bitkisinden elde edilebilecek ekonomik ürünler arasında: lavanta balı, lavanta çayı, lavantalı Türk kahvesi, lavanta dondurması, lavantalı gözleme, lavanta kesesi, lavanta demeti, lavantalı bebek, lavanta yastığı, lavanta yağı, lavanta sabunu, lavanta kolonyası, lavanta kremi, lavanta reçeli, lavantalı kurabiye, lavantalı muhallebi olduğu belirlenmiştir (Ongun et al., 2017). Lavanta alanlarında yürüyüş aktiviteleri, atlı yürüyüş, bisiklet, su sporları, tırmanma, kanyon geçişi, golf, balıkçılık, foto safari vb. tuzim aktivitelerinin yapılabildiği bildirilmiştir (Bilgiç et al., 2016: Ongun et al., 2018).

Sonuç ve Öneriler

Lavantanın arı merası olarak kullanılması hem arıcılık sektörü için hem de kırsal kalkınma içi önemli katkılar sunma potansiyeline sahiptir. Lavanta tarımının yaygınlaştırılması, arı sağlığının korunması ve bal kalitesinin artırılması açısından büyük önem arz etmektedir. Lavanta tarlalarının arı merası olarak kullanımı; arı popülasyonunun ve bal veriminin artırılmasına katkı sağlamakta, arı sağlığını olumlu yönde etkilemekte, üreticiye ek gelir sağlamakta, lavanta tarımına dayalı ticari ürünlerin çeşitlenmesi vb. katkı sağlama potansiyeline sahiptir. Lavanta balı; yüksek piyasa değeri ve özgün aroması ile diğer monofloral ballardan ayrılmaktadır. Lavanta yetiştiriciliğine bağlı arı meralarının yaygınlaştırılması kırsal kalkınma ve sürdürülebilir tarım uygulamaları açısından da büyük önem taşımaktadır. Lavanta çok yönlü kullanım alanları, ekonomik değeri ve ekolojik adaptasyon yeteneği ile dikkat çeken bir bitkidir. Tıbbi, kozmetik, gıda ve tarım sektörlerinde geniş bir yelpazede değerlendirilen bir bitki olup aynı zamanda arıcılık faaliyetleri için de önemli bir kaynaktır. Bu özellikleriyle lavanta, sürdürülebilir tarım ve kırsal kalkınma açısından önemli bir potansiyele sahip olup konu ile ilgi daha kapsamlı bilimsel araştırmalara ihtiyaç bulunmaktadır.

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EFFECTS OF BASE FERTILIZER APPLICATIONS ON SILAGE QUALITY OF SOME SILAGE CORN VARIETIES

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ABSTRACT

This study, conducted under Bingöl ecological conditions, aimed to determine the effects of two different base fertilizer applications on silage quality of some silage corn varieties. Eight different silage corn varieties (30B74, 94MAY66, DKC6442, DKC6777, EVEREST, HIDO, P32W86 and TK6063) and two different fertilizer types (DAP and organomineral) were used in the experiment. The study was carried out according to the split-plot experimental design in randomized blocks with three replications. Dry matter (DM), pH, crude protein (CP), crude cellulose (CS), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude ash (CA) and acid detergent lignin (ADL) were examined as quality parameters of silage. According to the research findings, the highest DM rate and the lowest CS, NDF and ADF rates were obtained from DAP fertilizer, while the lowest pH value was obtained from organomineral fertilizer. There was no statistical difference between fertilizer types in terms of CP, CA and ADL ratios. Among the silage corn varieties, the lowest CS, NDF, ADF, CA and ADL ratios were obtained from all varieties except 30B74, DKC6777 and TK6063. While no difference was observed between the varieties in terms of CP ratios, the lowest pH value was obtained from P32W86 variety and the highest DM ratios were obtained from 94MAY66 and EVEREST varieties. As

a result, it was determined that DAP fertilizer gave better results in terms of DM, CS, NDF, ADF ratios, which are important parameters of silage quality, and the other varieties except 30B74, DKC6777 and TK6063 varieties were also prominent in terms of the examined characteristics.

Keywords: Silage corn, dry matter, pH, crude protein, crude cellulose

TABAN GÜBRESİ UYGULAMALARININ BAZI SİLAJLIK MISIR ÇEŞİTLERİNİN SİLAJ KALİTESİ ÜZERİNE ETKİLERİ

ÖZET

Bingöl ekolojik koşullarında yürütülen bu çalışma, iki farklı taban gübresi uygulamasının bazı silajlık mısır çeşitlerinin silaj kalitesi üzerindeki etkilerini belirlemeyi amaçlamaktadır. Denemede sekiz farklı silajlık mısır çeşidi (30B74, 94MAY66, DKC6442, DKC6777, EVEREST, HİDO, P32W86 ve TK6063) ile iki farklı gübre türü (DAP ve organomineral) kullanılmıştır. Araştırma, tesadüf bloklarında bölünmüş parseller deneme desenine göre, üç tekrarlamalı olarak yürütülmüştür. Denemede silajın kalite parametreleri olarak kuru madde (KM), pH, ham protein (HP), ham selüloz (HS), nötr deterjanda çözünmeyen lif (NDF), asit deterjanda çözünmeyen lif (ADF), ham kül (HK) ve asit deterjanda çözünmeyen lignin (ADL) oranları incelenmiştir. Araştırma bulgularına göre en yüksek KM oranı ile en düşük HS, NDF ve ADF oranları DAP gübresinden alınırken, en düşük pH değeri organomineral gübreden alınmıştır. HP, HK ve ADL oranları açısından gübre türleri arasında istatistiksel bir farklılık görülmemiştir. Silajlık mısır çeşitleri arasında en düşük HS, NDF, ADF, HK ve ADL oranlarının 30B74, DKC6777 ve TK6063 çeşitleri dışında kalan diğer tüm çeşitlerden alındığı belirlenmiştir. HP oranları açısından çeşitler arasında bir farklılık gözlenmezken, en düşük pH değerinin P32W86 çeşidinden, en yüksek KM oranlarının da 94MAY66 ve EVEREST çeşitlerinden alındığı belirlenmiştir. Sonuç olarak silaj kalitesinin önemli parametreleri olan KM, HS, NDF, ADF oranları açısından DAP gübresinin daha iyi sonuçlar verdiği ve 30B74, DKC6777 ve TK6063 çeşitleri dışında kalan diğer çeşitlerin de incelenen özellikler açısından öne çıktığı belirlenmiştir.

Keywords: Silajlık mısır, kuru madde, pH, ham protein, ham selüloz

Giriş

Hayvancılığın sürdürülebilirliğinin sağlanmasında, kaba yem kaynaklarının güvenilir ve kaliteli bir şekilde temin edilmesi temel bir gereklilik olarak öne çıkmaktadır. Bu çerçevede, silaj, özellikle süt ve et üretimini artırmayı hedefleyen ruminant hayvan beslenmesinde hayati bir yem kaynağı haline gelmiştir. Silajlık mısır (*Zea mays* L.), yüksek düzeyde kuru madde verimi, sindirilebilirlik kapasitesi ve enerji içeriği gibi avantajlarıyla en yaygın tercih edilen silaj bitkileri arasında yer almaktadır (Yıldız ve ark., 2017; Karagöz, 2018).

Günümüz şartlarında hayvan beslenmesi açısından büyük bir öneme sahip olan silaj, dünya genelinde en çok mısır bitkisinden üretilmekte ve bu amaç doğrultusunda geniş ölçekte mısır tarımı yapılmaktadır. Mısır bitkisi, yüksek verimliliği, hayvanlar tarafından kolay sindirilebilir oluşu, lezzetli yapısı, yüksek kuru madde üretimi, yüksek enerji değeri, tamamen makinelerle üretilebilirliği ve işlenme kabiliyetinin son derece iyi olması gibi özellikleriyle dikkat çekmektedir. Bu unsurlardan dolayı, dünyada olduğu gibi ülkemizde de sıcak iklim tahılları arasında silaj üretimi için en çok tercih edilen bitkilerden biridir (Özata ve ark., 2012)

Türkiye İstatistik Kurumu'nun 2022 verilerine göre, 2021 yılında ülkemizde toplamda 5,2 milyon dekar alanda silajlık mısır ekimi gerçekleştirilmiş, bu ekimden 27,3 milyon ton üretim elde edilmiş ve dekar başına düşen verim 5208 kilogram olarak kaydedilmiştir (TÜİK, 2022).

Silajın kalitesi, hayvanların performansı ve yemden yararlanma düzeyi açısından önemli bir rol oynar. Kalite değerlendirmesi yalnızca kuru madde oranına bağlı kalmaz; aynı zamanda ham protein (HP), ham selüloz (HS), nötr ve asit deterjanda çözünmeyen lif içerikleri (NDF, ADF), ham kül (HK), asit deterjanda çözünmeyen lignin (ADL) ve pH gibi birçok kimyasal ve fiziksel parametre ile doğrudan ilişkilidir (Çaçan ve İşikten, 2019). Bu parametreler, silajın besin içeriğini ve fermentasyon kalitesini belirlemede etkili olur.

Bitkilerin ihtiyaç duyduğu anda ve uygun miktarda yapılan gübreleme, hem verimi hem de kaliteyi olumlu bir şekilde etkiler. Gübrenin tüm gelişim dönemlerinde bitkiyi desteklediği, bu etkinin ise kullanılan gübrenin türüne, dozuna ve uygulanma şekline bağlı olduğu belirtilmektedir (Çelebi ve ark., 2010).

Silaj kalitesini belirleyen en önemli tarımsal unsurlardan biri gübreleme stratejisidir. Özellikle tercih edilen taban gübresinin türü ile içeriği, bitkinin fizyolojik gelişimini ve bünyesinde barındırdığı besin maddelerinin dengesini önemli ölçüde etkileyebilmektedir. Son yıllarda geleneksel kimyasal gübrelerin yerine yaygınlaşan organomineral gübreler, toprak verimliliğini koruma yetenekleriyle birlikte silaj kalitesini artırma potansiyeline de sahip olduğu bilinmektedir.

İzmir'in ekolojik koşullarında gerçekleştirilen bir araştırmada, çeşitli mısır türlerinin silaj performansı, kalite ve verim değerleri bir yıl boyunca incelenmiştir. Araştırma sonuçlarına göre, kuru madde oranı %20,6-%29,0 arasında, ham protein oranı %6,16-%8,61 arasında, ham selüloz oranı %25,7-%33,4 arasında ve kuru ot verimi 2479-3608 kg/da arasında bulunmuştur. (Yıldız ve ark., 2017).

Kayseri ekolojik koşullarında NK Antria silajlık mısır çeşidi üzerinde yapılan bir çalışmada, farklı azotlu gübre dozlarının verim ve kalite özellikleri üzerindeki etkileri incelenmiştir. Araştırma kapsamında, farklı azot uygulamaları sonucunda mısırdan elde edilen ham protein oranının %6,88 ile %8,61, ham protein veriminin 65,25 ile 124,71 kg/da, ham kül oranının %5,78 ile %6,62, ADF oranının %18,69 ile %23,73 ve NDF oranının %43,98 ile %50,08 arasında değiştiği tespit edilmiştir. Ayrıca azot dozlarının artışıyla birlikte yeşil ot ve kuru ot veriminde de bir artış gözlendiği belirtilmiştir (Karagöz, 2018).

Akdeniz ekolojik koşullarında gerçekleştirilen ve iki yıl boyunca 14 farklı silajlık mısır çeşidinin verim ile kalite parametrelerinin değerlendirildiği araştırmada, ham protein oranı %8,80, ADF oranı %34,91, NDF oranı %59,7, ham kül oranı %7,2 ve KM oranı %61,7 olarak belirlenmiştir (Korkmaz ve ark., 2019).

Bingöl ekolojik koşullarda ana ürün olarak yetiştirilen silajlık mısır çeşitlerinin verim ve kalite parametrelerinin değerlendirildiği bir çalışmada, ham protein oranının %10,67 ile %12,50 arasında değiştiği, ham protein veriminin ise 230,5 ila 362,5 kg/da olduğu tespit edilmiştir. Ayrıca ADF oranı %18,53 ile %22 arasında, NDF oranı %26,21 ile %30,89 arasında, kalsiyum (Ca) oranı %0,28 ile %0,53 arasında, magnezyum (Mg) oranı %0,13 ile %0,16 arasında, fosfor (P) oranı %0,33 ile %0,36 arasında ve potasyum (K) oranı %2,40 ile %2,75 arasında olduğu tespit edilmiştir (Çaçan ve İşikten, 2019).

Orta Karadeniz'in ekolojik koşullarında bir yıl boyunca yetiştirilen silajlık mısır çeşitlerinin verim ve kalite özelliklerinin araştırıldığı çalışmada, ham protein oranları %5,01 ile %9,48 arasında değişirken, NDF oranları %42,40 ile %56 ve ADF oranları ise %29 ile %39,17 arasında farklılık göstermiştir (Yılmaz ve ark., 2020).

Bu araştırmada, farklı silajlık mısır çeşitlerinin silaj kalite parametreleri üzerindeki DAP ve organomineral gübre uygulamalarının etkileri incelenmiştir. Çalışmanın temel amacı, çeşit ve gübre etkileşimlerinin silaj kalitesine olan etkilerini ortaya koyarak yem üretiminde kalite optimizasyonuna katkı sağlamak olarak belirlenmiştir. Bu doğrultuda, bölge koşullarında silajlık mısır çeşitlerinin hem üretim miktarını hem de kalitesini artırmaya yönelik en uygun taban gübre türünün tespit edilmesi ve bu gübre türünün kalite üzerindeki etkisinin değerlendirilmesi hedeflenmiştir.

MATERYAL VE TÖNTEM

Materyal

Araştırma materyali olarak DKC6442, DKC6777, 94MAY66, Hido, Everest, 30B74, PR32W86 ve TK6063 olmak üzere toplam sekiz adet farklı silajlık mısır çeşidi seçilmiştir. Araştırma, 2020 yetiştirme sezonunda Bingöl Üniversitesi Ziraat Fakültesi Uygulama ve Araştırma sahasında gerçekleştirilmiştir. Uygulama sahası, Bingöl ili ile Genç ilçesi arasında yer almakta olup, coğrafi olarak 38° 48' 41.07" kuzey enlemleri ile 40° 32' 20.65" doğu boylamları arasında bulunmaktadır. Araştırma bölgesinin ortalama rakımı ise 1080 m'dir.

Çizelge 1. Araştırmanın yürütüldüğü döneme ait Bingöl ilinin 2020 yılı ile uzun yılların iklim verileri.

	Ortalama Sıcaklık (^{0}C)		Toplam Yağış (mm)		Nispi Nem (%)	
Aylar	**2020**	**Uzun yıllar**	**2020**	**Uzun yıllar**	**2020**	**Uzun yıllar**
Ocak	0.4	-2.2	81.4	136.5	65.2	72.8
Şubat	0.8	-0.9	102.5	131.0	67.0	71.0
Mart	7.5	4.7	265.8	131.3	69.1	65.2
Nisan	11.4	10.9	134.0	110.1	60.5	61.1
Mayıs	16.9	16.2	138.8	80.6	55.6	56.9
Haziran	22.4	22.2	10.0	21.1	40.6	44.3
Temmuz	27.0	26.7	5.7	6.9	35.3	37.2
Ağustos	26.5	26.7	0.6	4.9	29.9	36.0
Eylül	24.0	21.3	1.2	14.8	32.3	41.3
Ekim	17.1	14.5	0.0	69.0	36.3	56.4
Kasım	8.5	6.8	56.2	94.7	59.7	65.2
Aralık	3.1	0.7	43.0	131.1	72.0	73.1
Ortalama/Toplam	**13.8**	**12.3**	**839**	**932**	**51.9**	**56.7**

Bingöl Meteoroloji Genel Müdürlüğünden temin edilen veriler kapsamında, Bingöl iline ait aylık sıcaklık, toplam yağış ve nispi nem değerleri Çizelge 1'de sunulmuştur. İncelenen verilere göre, çalışmanın gerçekleştirildiği 2020 yılına ait aylık ortalama sıcaklık 13,8°C, toplam yağış 839 mm ve ortalama nispi nem oranı %51,9 olarak tespit edilmiştir. Ayrıca, 2020 yılı, uzun yıllar ortalaması (1990-2020) ile karşılaştırıldığında daha sıcak bir yıl olmuş; buna karşın yağış miktarı ve nispi nem oranı daha düşük kaydedilmiştir. Deneme alanının toprak özellikleri Çizelge 2'de sunulmuştur.

Çizelge 2. Araştırmanın yürütüldüğü deneme alanının toprak özellikleri.

Parametre	**Metot**	**Sonuç**	**Açıklama**
Organik madde (%)	Walkley-Black	1,09	Düşük
Kireç (%)	Kalsimetrik	0,41	Düşük
Saturasyon (%)	Su ile doygunluk	73	Killi-Tınlı
pH	Potansiyometrik	6,26	Hafif Asidik
Tuzluluk	(EC metre)	0.014	Tuzsuz
P (kg/da)	Olsen-Spektro	7,60	Orta
K (kg/da)	A.Asetat-Flame	18,27	Düşük

Metot

Tarla denemesi, ilkbahar döneminde gerçekleştirilen toprak hazırlığının ardından, 23 Haziran 2020 tarihinde kurulmuştur. Deneme, tesadüf bloklarında bölünmüş parseller deneme desenine göre üç tekrarlı olacak şekilde planlanmıştır. Bloklar arasındaki mesafe 1 metre, sıra arası mesafeler 70 cm, sıra üzeri mesafeler ise 12 cm olarak belirlenmiştir. Her bir parsel, 5 metre uzunluğunda ve 4 sıradan oluşacak şekilde düzenlenmiştir.

Mısır tarımında gübreleme uygulamaları genellikle saf madde bazında dekar başına 15-20 kg azot ve 8-12 kg fosfor oranlarında gerçekleştirilmektedir. Uygulanan toplam gübre miktarının ekim sırasında verilen kısmı, genellikle dekar başına ortalama 30 kg DAP gübresi ile eşdeğerdir. Bu çalışmada da ekim esnasında denemeye, dekar başına 30 kg DAP gübresi ile 30 kg organomineral gübresi uygulanmıştır.

Bingöl SÜTAŞ tarafından sağlanan organomineral gübre, Tarım ve Orman Bakanlığı tarafından onaylanmış bir üründür ve daima bu yetkili kurumdan temin edilebilmektedir. Organomineral gübrenin içeriği, %6 azot, %10 fosfor ve %6 potasyum olacak şekilde formüle edilmiştir. Ticari olarak "SÜTAŞ 6-10-6+10SO3+ME" adı ile bilinmektedir. Kimyasal DAP gübresinin (%18 N, %46 P_2O_5) içeriği ile organomineral gübrenin (%6 N, %10 P_2O_5, %6 K_2O) bileşimi arasında farklılıklar görülmektedir. Ancak, üretim açısından dekara uygulanacak 30 kg kimyasal DAP gübresinin mi yoksa ekim sırasında dekara verilecek 30 kg organomineral gübrenin mi daha faydalı olabileceği araştırılmıştır. Bitki boyu 70-80 cm olduğu zaman boğaz doldurma ve yabancı ot kontrolü işlemi yapılmıştır. Bu işlemler ile birlikte bu aşamada dekara 15 kg/da N gelecek şekilde Üre gübresi, üst gübre olarak tüm parsellere verilmiştir. Deneme alanı düzenli bir şekilde salma sulama sistemi ile sulanmıştır. Hasat, 06-20.10.2020 tarihlerinde silajlık mısır çeşitlerinin süt olum devrelerine ulaşma dönemleri esas alınarak yapılmıştır.

Silaj kalitesini belirleyen temel parametreler; kuru madde (KM), pH, ham protein (HP), ham selüloz (HS), nötr deterjanda çözünmeyen lif (NDF), asit deterjanda çözünmeyen lif (ADF), asit deterjanda çözünmeyen lignin (ADL) ve ham kül (HK) oranlarıdır. Hasat edilen bitkiler öğütüldükten sonra vakum torbalarına konularak 60 gün silajlanmış ve silaj süzüntülerinin pH'ı ölçülmüştür. Ardından, yeşil ot ve silaj örneklerinin kuru madde oranları belirlenmiş, elde edilen kuru örnekler öğütülerek Kjeldahl yöntemiyle azot ve ham protein oranları hesaplanmıştır (AOAC, 1990). NDF, ADF ve ADL analizleri Van Soest ve ark. (1991) metoduna göre, ham kül oranı ise 550 °C'de yakma yöntemiyle tespit edilmiştir. Deneme, "tesadüf bloklarında bölünmüş parseller deneme desenine" göre üç tekerrürlü, iki gübre çeşidi ana parsellere, silajlık mısır çeşitleri ise alt parsellere gelecek şekilde kurulmuş ve yürütülmüştür. Gübre çeşitleri ile silajlık mısır çeşitleri arasındaki benzerlik ve farklılıklar, $P \leq 0,05$ önem seviyesinde LSD testi kullanılarak değerlendirilirken, gübre x çeşit etkileşimi $P \leq 0,05$ önem seviyesinde Tukey testi aracılığıyla karşılaştırılmıştır.

Bulgular ve Tartışma

Çalışmada iki farklı taban gübresi uygulamasının silajlık mısır çeşitlerinin silaj kalitesine etkileri değerlendirilmiştir. İncelenen özelliklere ait varyans analiz sonuçları Çizelge 3'te verilmiştir. Gübre uygulamaları açısından ham protein, ham kül ve ADL değerlerinin, çeşit açısından ham protein değerinin, çeşit x gübre interaksiyonu açısından ise ADL değerinin istatistiksel olarak önemli olmadığı tespit edilmiştir. Geriye kalan diğer özellikler arasındaki farklılıkların istatistiksel olarak önemli olduğu görülmüştür.

Çizelge 3. İncelenen özelliklerin varyans analizi sonucu elde edilen F değerleri ve önemlilik kontrolü.

	SD	KM	pH	HP	HS	NDF	ADF	HK	ADL
Bloklar	2	0.07	1.9	0.01	0.16	0.003	0.12	0.15	0.59
Çeşit	7	38.7**	9.7**	1.8	14.1**	9.69**	14.5**	7.05**	10.5**
Gübre	1	261.6**	18.8**	0.03	40.5**	45.2**	32.7**	0.04	2.73
Çeşit x Gübre	7	50.0**	8.2**	2.8**	5.7**	5.6**	3.91**	4.91**	1.48

*: P≤0.05, **: P≤0.01 düzeyinde önemlidir.

Silajlık mısır çeşitlerine ait silajın kalite özellikleri Çizelge 4'te verilmiştir. Çeşitler arasında en yüksek KM oranı EVEREST ve 94MAY66 çeşitlerinden, en düşük KM oranı ise DKC6777 ve TK6063 çeşitlerinden elde edilmiştir. İnteraksiyon açısından en yüksek KM oranı %36,1 ile DKC6442 çeşidinde DAP gübresinden elde edilirken, en düşük değer %26,6 ile DKC6442 çeşidinde ve organomineral gübreden elde edilmiştir. Gübre türleri bazında ortalama KM değerlerine bakıldığında ise DAP gübresinde %32,0, organomineral gübrede ise %29,2 olarak tespit edilmiştir. Mısır çeşitlerinin silajlarındaki ortalama KM değerleri, Yıldız ve ark (2017)'nın bulgularından (%20.6-29.0) yüksek iken, Başaran ve ark (2017)'nın belirlemiş olduğu değerler (%28.36-34.58) ile uyumlu olduğu tespit edilmiştir. Bu sonuçlar, özellikle DAP gübresinin KM oranını optimum seviyede tutmada etkili olduğunu ortaya koymaktadır.

Araştırma sonuçlarına göre, pH değerleri 3.62 ile 3.81 arasında değişim göstermiştir. Çeşitler arasında en yüksek pH değeri EVEREST çeşidinden, en düşük pH değeri ise P32W86 çeşidinden alınmıştır. Ortalama pH değeri DAP gübresinde 3.73, organomineral gübrede ise 3.70 olarak belirlenmiştir. İnteraksiyon açısından en düşük pH değeri organomineral gübre uygulamasında ve DKC6777 çeşidinde, en yüksek pH değeri de DAP gübresinde ve EVEREST çeşidinden alınmıştır. Çalışma kapsamında elde edilen tüm ölçümler ideal silaj pH aralığında (3.7-4.0) yer almış ve başarılı bir fermentasyon sürecinin gerçekleştiği tespit edilmiştir.

HP oranı, %5.06 ile %6.99 arasında değişiklik göstermiştir. Çeşitler ve gübre türleri arasında istatistiksel bir fark gözlenmezken, interaksiyon açısından en yüksek HP oranı organomineral gübre kullanılarak 30B74 çeşidinde (%6.99) elde edilirken, en düşük oran ise yine organomineral gübreyle TK6063 çeşidinde (%5.06) tespit edilmiştir. Özata ve ark. (2012) yaptıkları çalışmada HP oranını %5.2-9.06 aralığında tespit ederken, Başaran ve ark. (2017) %6.02-9.39 aralığında tespit etmişlerdir. Elde edilen bulgular, diğer araştırmacıların bulgularından nispeten düşük olmuştur.

Çizelge 4. Bazı silajlık mısır çeşitlerine ait silajın kalite özellikleri.

	Kuru Madde Oranı (%)			pH		
Çeşitler	**DAP**	**OM**	**Ortalama**	**DAP**	**OM**	**Ortalama**
30B74	29,6 e	32,0 cd	30,8 BC	3,74 a-d	3,74 a-d	3,74 AB
94MAY66	34,0 b	30,2 e	32,1 A	3,73 a-d	3,76 abc	3,75 AB
DKC6442	36,1 a	26,6 g	31,4 AB	3,80 ab	3,70 c-f	3,75 AB
DKC6777	29,2 ef	27,6 fg	28,4 D	3,74 a-d	3,62 f	3,68 CD
EVEREST	34,4 ab	30,2 de	32,3 A	3,81 a	3,70 cde	3,76 A
HİDO	30,4 de	29,6 e	30,0 C	3,72 b-e	3,72 b-e	3,72 ABC
P32W86	32,7 bc	29,9 e	31,3 AB	3,65 ef	3,68 def	3,66 D
TK6063	29,4 ef	27,7 fg	28,5 D	3,71 cde	3,70 cde	3,70 BCD
Ortalama	**32,0 A**	**29,2 B**	**30,6**	**3,73 A**	**3,70 B**	**3,72**
	Ham Protein Oranı (%)			**Ham Selüloz Oranı (%)**		
Çeşitler	**DAP**	**OM**	**Ortalama**	**DAP**	**OM**	**Ortalama**
30B74	5,70 bc	6,99 a	6,34	28,1 a	26,2 abc	27,2 A
94MAY66	5,86 bc	6,08 abc	5,97	22,8 cd	25,7 abc	24,3 B
DKC6442	5,48 bc	6,50 ab	5,99	21,6 d	27,4 ab	24,5 B
DKC6777	5,65 bc	5,47 bc	5,56	28,5 a	28,9 a	28,7 A
EVEREST	6,52 ab	5,62 bc	6,07	21,3 d	25,6 abc	23,5 B
HİDO	5,11 c	5,67 bc	5,39	23,9 bcd	25,8 abc	24,8 B
P32W86	6,47 ab	5,31 c	5,89	23,9 bcd	25,6 abc	24,8 B
TK6063	5,63 bc	5,06 c	5,34	26,0 abc	28,4 a	27,2 A
Ortalama	**5,80**	**5,84**	**5,82**	**24,5 B**	**26,7 A**	**25,6**
	NDF Oranı (%)			**ADF Oranı (%)**		
Çeşitler	**DAP**	**OM**	**Ortalama**	**DAP**	**OM**	**Ortalama**
30B74	56,9 a	51,8 a-d	54,3 AB	32,2 ab	30,2 abc	31,2 AB
94MAY66	46,8 cde	52,4 a-d	49,6 BC	26,7 cde	29,5 bcd	28,1 C
DKC6442	45,7 de	55,6 a	50,6 BC	25,1 de	30,9 abc	28,0 C
DKC6777	56,3 a	59,2 a	57,7 A	33,1 ab	34,0 a	33,6 A
EVEREST	42,7 e	54,3 abc	48,5 C	24,5 e	29,2 bcd	26,8 C
HİDO	51,5 a-d	54,8 ab	53,2 ABC	27,0 cde	29,3 bcd	28,2 C
P32W86	47,3 b-e	53,6 a-d	50,4 BC	27,7 cde	29,6 bc	28,6 BC
TK6063	53,2 a-d	59,3 a	56,2 A	29,9 abc	32,6 ab	31,2 AB
Ortalama	**50,0 B**	**55,1 A**	**52,6**	**28,3 B**	**30,7 A**	**29,5**
	Ham Kül Oranı (%)			**ADL Oranı (%)**		
Çeşitler	**DAP**	**OM**	**Ortalama**	**DAP**	**OM**	**Ortalama**
30B74	5,03 a	4,01 bcd	4,52 A	3,73	4,04	3,88 AB
94MAY66	3,77 cd	4,45 a-d	4,11 AB	3,51	3,62	3,56 BCD
DKC6442	3,80 cd	3,73 d	3,76 B	3,14	3,63	3,38 CD
DKC6777	4,71 abc	4,14 a-d	4,42 A	4,10	4,16	4,13 A
EVEREST	3,70 d	3,92 bcd	3,81 B	3,51	3,20	3,35 CD
HİDO	4,69 abc	4,54 a-d	4,62 A	3,07	3,20	3,13 D
P32W86	4,05 bcd	4,25 a-d	4,15 AB	3,58	3,56	3,57 BCD
TK6063	4,30 a-d	4,85 ab	4,57 A	3,55	3,69	3,62 BC
Ortalama	**4,25**	**4,24**	**4,24**	**3,52**	**3,63**	**3,58**

OM: Organomineral, DAP: Diamonyum fosfat.

En yüksek HS oranı 30B74, DKC6777 ve TK6063 çeşitlerinden elde edilirken, geriye kalan diğer çeşitler HS oranı açısından en düşük değeri veren grubu oluşturmuştur. İnteraksiyon açısından da en yüksek HS oranlarının her iki gübre uygulamasında da DKC6777, 30B74 ve TK6063 çeşitlerinden alındığı görülmektedir. Ortalamalara bakıldığında DAP gübresinden daha düşük HS oranının elde edildiği belirlenmiştir. Bu değerler Çakmak ve ark. (2013)'ının tespit ettiği HS oranlarından (%18.76-21.76) yüksektir.

En yüksek NDF oranı 30B74, DKC6777 ve TK6063 çeşitlerinden alınırken, en düşük NDF oranı EVEREST çeşidinden alınmıştır. İnteraksiyon açısından bakıldığında NDF oranının %42.7-59.3 arasında değişim gösterdiği ve en düşük NDF oranının DAP gübresi uygulaması

ile EVEREST çeşidinden alındığı görülmektedir. Gübre türleri açısından DAP gübre uygulaması ile daha düşük NDF oranı elde edildiği görülmüştür. Elde edilen bulgular, Başaran ve ark. (2017)'ını tespit ettiği %50.53-60.40 ile Özata ve ark. (2012)'ının tespit ettiği %47.5-58.9 NDF değerleri ile örtüşmektedir.

En yüksek ADF oranı 30B74, DKC6777 ve TK6063 çeşitlerinden alınırken, en düşük ADF oranı geriye kalan diğer çeşitlerden alınmıştır. İnteraksiyon açısından bakıldığında ADF oranının %24.5-34.0 arasında değişim gösterdiği ve en düşük ADF oranının DAP gübresi uygulaması ile EVEREST çeşidinden alındığı görülmektedir. Gübre türleri açısından DAP gübre uygulaması ile daha düşük ADF oranı elde edildiği görülmüştür. Özata ve ark. (2012), yaptıkları çalışmada ADF oranını %24.1-40.9 değerleri arasında tespit ederken, Başaran ve ark. (2017) ADF oranını %31.30-37.47 değerleri arasında bulduklarını bildirmişlerdir. Yıldız ve Erdoğan (2018) yaptıkları çalışmada ADF oranını %30.47 olarak tespit etmiştir. Bu bağlamda elde edilen bulgular, literatürdeki diğer sonuçlar ile örtüşmektedir.

En düşük HK oranı DKC6442 ve EVEREST çeşitlerinden alınırken, geriye kalan diğer çeşitler en yüksek değeri veren grubu oluşturmuştur. Gübre türleri arasında bir fark görülmezken, interaksiyon açısından HK oranları %3.70-5.03 arasında değişiklik göstermiştir. En yüksek HK oranı DAP uygulaması ile 30B74 çeşidinden alınırken, en düşük HK oranı yine DAP gübre uygulaması için EVEREST çeşidinden ve organomineral gübre uygulaması ile DKC6442 çeşidinden alınmıştır. Alaca ve Parlak (2017) HK oranı için %6.77 değerini, Taş ve ark. (2017) %7.60 değerini bulduklarını bildirmişlerdir. Linn ve ark. (2006) silajlık mısırda yem kalitesi için ideal HK değerinin %6'dan düşük olması gerektiğini bildirmiştir. Bu bağlamda tüm çeşitlerin HK içeriklerinin %6'dan düşük olduğu görülmektedir.

Çeşitlerin ADL değerleri %3.13 ile %4.13 arasında değişiklik göstermiştir. En düşük ADL oranı HİDO çeşidinden, en yüksek ADL oranı ise DKC6777 çeşidinden alınmıştır. Gübre türleri ile interaksiyon önemsiz bulunmuştur. Elde edilen ADL değerleri, Taş ve ark. (2017)'ının bulduğu %3.81 değerinden düşük, Alaca ve Parlak (2017)'ın bildirdiği %2.62 değerinden yüksek olduğu tespit edilmiştir.

Sonuç ve Öneriler

Yapılan araştırmada, DAP gübresinin özellikle kuru madde oranı, lif içeriği (NDF, ADF) ve ham selüloz gibi kalite ölçütlerinde daha olumlu etkiler sağladığı ortaya konmuştur. Bu, DAP gübresinin hem silaj verimini artırmada hem de sindirilebilirliği iyileştirmede önemli bir avantaj sunduğunu göstermektedir. Öte yandan, organomineral gübrelerin de belirli kalite parametrelerinde kayda değer yararlar sağladığı tespit edilmiştir. Bu sonuçlar, organik madde açısından zengin olan bu tür gübrelerin toprak sağlığını koruma, kimyasal gübre kullanımını azaltma ve sürdürülebilir tarım uygulamalarına destek sağlama açısından önemli bir potansiyele sahip olduğunu vurgulamaktadır.

Kalite parametrelerinde en yüksek verimi elde etmek adına DAP gübresi, kısa vadede etkili bir seçenek olarak görülebilir. Ancak, uzun vadede toprak sağlığını korumak ve sürdürülebilirliği teşvik etmek için organomineral gübrelerin kullanımı öne çıkarılmalı, bu gübrelerin faydalarını artırmaya yönelik entegre gübreleme stratejileri geliştirilmelidir. Aynı zamanda, bitki çeşit seçiminin ve gübre stratejisinin bir arada ele alınması büyük önem taşımaktadır. Bu kapsamda, farklı iklim ve toprak şartlarında uzun süreli uygulamaların etkilerini değerlendiren kapsamlı araştırmalara ihtiyaç duyulmaktadır.

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MORTALITY RISK MANAGEMENT PRACTICES AMONG POULTRY FARMERS IN ENUGU STATE, NIGERIA

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ABSTRACT

The study ascertained mortality risk management practices among poultry farmers in Enugu State, Nigeria. A multistage sampling procedure was used to select 60 poultry farmers. Data were collected using structured interview schedule and analyzed using mean score and presented using frequency count and percentage. Results revealed that mortality risk sources faced by farmers include; heat stress (95.0%) excessive cold/harmattan (91.7%) etc. Result also showed that farmers have a positive attitude towards mortality risks management practices in the area. Results revealed that majority (97.5%) of the farmers have high knowledge on mortality risk management practices. The results further revealed that the mortality risk management practices among poultry farmers include; clean water and proper ventilation to prevent health issues ($\bar{x}$=4.87) and monitor and control the feed quality of birds to reduce the risk of health issues ($\bar{x}$= 4.82). Lastly, major constraint faced by the farmers on mortality risk management practices include; costly insurance coverages ($\bar{x}$=1.95), fluctuations in feed prices ($\bar{x}$=1.88), inadequate facilities and technologies ($\bar{x}$=1.78) etc. Therefore, the study recommends that Therefore, the study recommends that Enugu State government and non-governmental organizations should support poultry farmers in making available affordable insurance policies that can help them to mitigate against mortality risk in their farms.

Keywords: Poultry, Farmers, Mortality, Risk, Management, Practices

Introduction

Agriculture remains the largest sector in Nigeria contributing an average of 24% to the nation's GDP over the past seven years (2013 – 2019). In addition, the sector employs more than 36% of the country's labour force, a feat which ranks the sector as the largest employer of labour in the country (Oyaniran, 2020). It is broadly divided into four sectors: crop production, fishing, forestry and livestock (poultry). Poultry production in Nigeria contributes to the solution of unemployment problems. It can open new jobs indirectly through the development of industries connected with poultry products such as feed industries, slaughtering industries, food freezing, packaging industries, and industries producing machines and technical tools necessary for poultry production. It can also be considered as one of the most important sources of cheap protein. (Wahyono & Utami, 2019). Poultry production is the art of raising birds domestically or commercially, primarily for meat and eggs. (Food and Agriculture Organization, (FAO)2021). Poultry production is a significant part of the global agricultural industry, providing a valuable source of protein and employment for millions of people worldwide. The growth of the poultry industry has been driven by increasing demand for poultry products, particularly in developing countries, as well as improvements in genetics, nutrition, and management practices.

However, poultry farming is subjected to various risks including production risks, market risks, financial risks, and biological risks such as infectious diseases. These risks can result in significant economic losses, reduced productivity, and negative impacts on animal welfare (World Organization for Animal Health (WOAH), 2021). Risk is an inherent feature of modern poultry production. When birds die prematurely, farmers lose the investment they made in acquiring and raising them, including the cost of feed, labor, and medication. Additionally, high mortality rates may result in a reduction in the supply of poultry products, leading to a decrease in revenue for farmers and potentially impacting the overall supply of animal protein. Nigeria has faced several challenges in poultry farming due to risks associated with the industry. These challenges include disease outbreaks, inadequate biosecurity measures, high cost of production, and limited access to finance. Limited access to credit facilities makes it difficult for poultry farmers to invest in necessary infrastructure and technology, impeding industry growth and modernization. (Igbokwe & Adebayo, 2020). In particular, the failure to rise up to this challenge to save the industry could lead to a serious reduction in poultry production and protein intake of the people. Risk management strategies play a crucial role in poultry farming to mitigate potential risks and ensure the overall success and sustainability of the industry. Implementing risk management strategies in poultry farming is essential for disease control and maintaining biosecurity. Another strategy is diversifying production systems, such as integrating poultry farming with other livestock or crop enterprises, which can reduce the dependency on a single production, thereby minimizing the risks associated with market fluctuations and disease outbreaks. (Kariuki & Kaguongo, 2019).

Also, risk management strategies are crucial to mitigate the impact of market volatility and price fluctuations on poultry farming. Effective risk management practices are crucial for poultry farmers to mitigate the effects of various risks associated with the enterprise. According to Adeyonu et al (2021) who conducted a study in south-west, Nigeria, production risk, financial risk, and human risk were perceived by farmers as the most common risks in the poultry business. Farmers have adopted disease prevention and financial management strategies to mitigate these risks. The study also found that years of experience in poultry business, value of poultry, and production risk are important determinants of disease prevention and financial management strategies adopted by the respondents.

In a report by the Enugu State Ministry of Agriculture, it was stated that the poultry industry in the state provides employment opportunities for a large number of people and generates substantial income for farmers and the government (Enugu State Ministry of Agriculture, 2019). Despite this contribution of poultry farming, these risks against it cannot be overemphasized. Poultry farming has significant potential in Enugu State. The state is located in the southeastern part of Nigeria and has a population of over 3.2 million people. The state's climate is suitable for poultry farming, and there is a high demand for poultry products in the state and its neighboring states. Risk in poultry production poses significant dangers to investments in the industry and the degree of mortality risk in poultry farms in Enugu State varies depending on several factors such as the type of poultry operation, management practices, disease prevalence, and environmental conditions. However, mortality rates in poultry production in Enugu State can be high, with some reports indicating mortality rates of up to 30% in some farms. (Enugu State Ministry of Agriculture, 2019). Few studies on poultry management practices have recently been conducted. For instance, Eze et al. (2017) ascertained biosecurity measures used by poultry farmers in Enugu State, Nigeria and Onoerigho et al. (2014) examined socio-economic traits of small-scale poultry farmers and level of adoption of poultry management practices before and after training in Enugu State, Nigeria Amongst these studies, none seemed to have researched on management practices among poultry farmers as it relates to mortality risk in Enugu State, Nigeria. There seems to be a research gap in Enugu State on mortality risk management practices among poultry farmers.

Objective of the study

The overall objective of the study was to ascertain the mortality risk management practices among poultry farmers in Enugu State, Nigeria. Specifically, the study sought to:

i. ascertain the mortality risk sources in poultry farms;
ii. ascertain attitude of the farmers toward mortality risk;
iii. ascertain farmer's knowledge level on mortality risk management practices;
iv. ascertain information needs of poultry farmers on mortality risk management practices;
v. identify mortality risk management practices among poultry farmers; and
vi. identify constraints to mortality risk management practices.

Materials and methods

Study area

The study was carried out in Enugu State, Nigeria. Enugu State is in the southeastern region of Nigeria. It is located on a Latitude of 6° 27' 9.60" N and Longitude 7° 30' 37.20., The state has a total land area of approximately 7,161 square kilometers and is bordered by Benue State to the north, Kogi State to the northwest, Anambra State to the west, Abia State to the south and Ebonyi State to the east (Britannica, 2022).). There are various types of poultry farms in Enugu State, ranging from small-scale backyard farms to large-scale commercial farms. The poultry farms in the state produce a variety of poultry products such as eggs, meat, and feathers. In terms of tourism, Enugu State has several attractions, including the Ngwo Pine Forest and Waterfall, the Nike Lake Resort, the Awhum Waterfall, and the Ezeagu Tourist Complex. These natural attractions and cultural sites draw tourists from within and outside the country and contribute to the state's economy. There are many hotels and eateries in Enugu State that have given poultry businesses good patronage by sourcing their poultry products from

local poultry farms in the state.

Population and sampling procedure

The population for this study comprised all poultry farmers in Enugu state, Nigeria. A multistage sampling procedure was used in selecting respondents. In the first stage, two local government areas (Enugu-South and Nsukka) were purposively selected for the study because of their prominence in poultry production. In the second stage, three town communities were selected using purposive sampling technique in each local government area because of the availability of poultry farms in those areas. In the third stage, ten poultry farmers were selected using snowball sampling technique giving a total number of 60 farmers for the study. Data for the study were collected using structured interviews schedule. Mortality risk sources in poultry farms. Respondents were asked to tick from a list of eleven possible mortality risk sources and respondents were asked to tick either Yes (1) or No (0). Attitude of farmers toward mortality risk management practices in poultry farming. To achieve this a list of fifteen positive and negative attitude questions was given on a five-point Likert-type scale of strongly agreed (5), agreed (4), undecided (3), strongly disagreed (2), and disagreed (1). The values were added up to obtain a mean score of 3.0. Any variable with a mean score of equal and greater than 3.0 was regarded as positive attitude towards mortality risk management practices while any variable with a mean score less than 3.0 was termed as negative attitude towards mortality risk management practices. Knowledge on mortality risk management practices. To achieve this, a list of 21 positive and negative knowledge questions was given to the respondents. The respondents were asked to tick yes or no against each response option. Every correct response attracted a score of 1 while incorrect responses attracted a score of 0. against the questions. The correct answers from the twenty-one knowledge questions provided used to categorize the knowledge level thus: 0 (no knowledge), 1-7 (low knowledge) 8-14 (moderate knowledge) and 15 -21(high knowledge). Information needs among poultry farmers on mortality risk management practices. To achieve this, a list of perceived information needs was presented to the farmers to indicate either yes or no. Mortality risk management practices employed by the respondents. To achieve this, a list of twelve mortality risk management practices and respondents were asked to indicate using a five-point Likert-type scale of strongly agreed (5), agreed (4), undecided (3), strongly disagreed (2), and disagreed (1). The values were added up to obtain a mean score of 3.0. Any variable with a mean score of equal and greater than 3.0 was regarded as a major mortality risk management practice while any variable with a mean score less than 3.0 was termed as not a mortality risk management practice. Constraints to mortality risk management practices faced by the respondents. This was measured by asking the respondents to indicate from a list of possible constraints encountered in mortality risk management practices on a three-point Likert-type scale of no constraint, low extent, and no extent with nominal values of 0, 1, and 2 respectively. The values were added to obtain a mean score of 1.0. Any variable with a mean score of equal and greater than 3.0 was regarded as a major constraint to mortality risk management practice while variables with a mean score less than 3.0 was termed as minor constraints to mortality risk management practices.

Data analysis

Variables in objectives 1,3, and 4 were presented using frequency count percentage and mean score. Variables in objectives 2,5 and 6 were analyzed using mean scores. IBM-SPSS Statistics version 21.0 was used for data analysis.

Findings and Discussion

Mortality risk sources in poultry farms

Results in Table 1 show that mortality risk sources include: heat stress (95.0%), excessive cold/harmattan (91.7%), physical injuries while handling the bird (70.0%), contaminated feeds (30.0%), and floods (10.0%). This shows that heat stress is a major environmental condition that negatively impacts the well-being of various avian species. In chickens, heat exposure is associated with disruption of metabolic and immune system function and an increased risk of mortality. Techniques to mitigate exposure to high temperatures have been discussed in depth, and most research suggested that the root cause of heat stress-induced physiological aberrations is alterations in the stress response and reduced food intake. (Bohler et al 2021).

Furthermore, excessive cold or harmattan can also pose a significant risk to birds. Cold weather can cause birds to use more energy to maintain their body temperature, which can lead to weight loss and decreased immune function. Additionally, cold weather can cause frostbite and other physical injuries. Birds use more energy to maintain their body temperature in cold weather, which can lead to weight loss and decreased immune function. It's important for bird owners to take measures to protect their birds from these environmental stressors. This can include providing adequate shelter, ensuring access to clean water and nutritious food, and implementing proper vaccination programmes.

Table 1: Mortality risk sources in poultry farm

Mortality risk sources	Frequency(f)	Percentage(%)
Zoonotic diseases	21	35.0
Allergies	21	35.0
Excessive cold/harmattan	55	91.7
Physical injuries while handling birds	42	70.0
Heat stress	57	95.0
Floods	6	10.0
Predators	30	50.0
Parasitic infestations	40	66.7
Poor water and feed management	22	36.7
Contaminated feeds	18	30.0
Improper vaccination programs	40	66.7

Source: Field survey, 2023

Attitude of farmers towards mortality risk management practices in poultry farming

Data in Table 2 reveal the attitude of farmers towards mortality risk management practices which include: Proactive approach to risk management is more effective than a reactive approach ($\bar{x}$ =4.80), risks of poultry farmers are managed with proper risk management strategies ($\bar{x}$ = 4.77), risks in poultry farming can be reduced with proper training and knowledge ($\bar{x}$ =4.77), risk management is an essential part of a successful poultry farming ($\bar{x}$ =

4.75), open to learning about new risk management strategies to improve ability to manage risks in poultry farm ($\bar{x}$ = 4.73), potential benefits of poultry farming outweigh the risk ($\bar{x}$ =4.57), confident to identify and manage risk in poultry farm ($\bar{x}$ =4.65), considering the potential risks in poultry farming when making decisions ($\bar{x}$=4.52), taking on higher levels of risk in poultry farming can lead to higher rewards ($\bar{x}$=4.52) etc. The findings reveal that the respondents have a positive attitude towards mortality risk management practices in their poultry farming. This indicates a generally positive outlook on risk management in poultry production. Respondents' inclination to perceive risks as manageable and rewards as outweighing risks reflects an optimistic mindset. The willingness to invest time, and resources, and collaborate for risk mitigation suggests a proactive approach. Belief in training, knowledge, and proactive strategies underscores confidence in risk reduction.

Farmer's believe that proactive risk management is more effective than a reactive approach. this is because a proactive approach involves identifying and addressing potential risks before they escalate into significant problems. This helps prevent or minimize negative consequences, such as disease outbreaks or production disruptions, which is more effective and less costly than reactive measures taken after the damage has occurred. Poultry farmers, like any other `farmers, prefer a proactive approach over a reactive approach because it involves planning for the future and taking into consideration potential problems that may arise. This can help prevent issues before they occur and save time, costs, and effort in the long run. On the other hand, a reactive approach involves managing issues as they arise, without appropriate planning or arrangements. **(**Sikdar, 2019). The risks of poultry farmers are managed with proper risk management strategies and Risks in poultry farming can be reduced with proper training and knowledge. According to Adeyonu et al. (2021), poultry farmers in South-West, Nigeria perceive production risk, financial risk, and human risk as the most important risks in their business. Farmers have adopted disease prevention and financial management strategies to mitigate the effects of various risks.

Table 2: Respondent's attitude towards mortality risk in poultry farming

Attitude statements	Mean	Std deviation
Risks in poultry farming are unavoidable	4.60	1.04
The potential benefits of poultry farming outweigh the risk	4.57	0.62
Risks of poultry farmers are managed with proper risk management strategies	4.77	0.43
Comfortable taking risks in poultry farming	4.37	0.74
The risks of poultry farming are too high to manage	3.73	1.45
Always willing to invest time and resources into risk management strategies to mitigate risks on my farm	4.68	0.68
Risks in poultry farming can be reduced with proper training and knowledge	4.77	0.56
Confident in identifying and managing risk on my farm	4.65	0.61
The risks of poultry farming are unpredictable and can be difficult to manage	4.13	1.14
Open to learning about new risk management strategies to improve the ability to manage risks	4.73	0.45
Risk management is an essential part of successful poultry farming	4.75	0.44
Always consider the potential risks in poultry farming when making decisions	4.52	0.60
A proactive approach to risk management is more effective than a reactive approach	4.80	0.63
Willing to collaborate with other farmers to manage risks in my farm	4.37	1.09
Taking on higher levels of risk in poultry farming can lead to higher rewards	4.52	1.03

Sources: Field survey, 2023.

Knowledge level on mortality risk management practices

Figure 1 shows that the majority (97.5%) of the respondents have high knowledge about mortality risk management practices while 2.5% have moderate knowledge about mortality risk management practices, this result showed that the majority of the poultry farmers in the study area are highly knowledgeable about mortality risk management practices. The majority of respondents exhibited a remarkably high level of knowledge in various critical aspects of poultry farming, including risk management, biosecurity, nutrition, technology, disease prevention, and business considerations. However, little proportion of respondents showed moderate knowledge levels, particularly in terms of local regulations and reproductive efficiency. Poultry farmers may have a high level of knowledge of mortality risk management practices because it is essential for the success of their business. Mortality risk management practices help to reduce the incidence of disease, morbidity, and mortality in poultry, which can have a significant impact on the profitability of the farm. By understanding and implementing effective mortality risk management practices, poultry farmers can improve the health and

productivity of their birds, leading to increased revenue and reduced losses. (Otunaiya et al. 2020)

In addition, there may be various resources available to poultry farmers to help them learn about mortality risk management practices. For example, government agencies, industry organizations, and educational institutions may offer training programs or expert consultations to help poultry farmers improve their knowledge and skills in this area. By taking advantage of these resources, poultry farmers can increase their knowledge and understanding of effective mortality risk management practices.

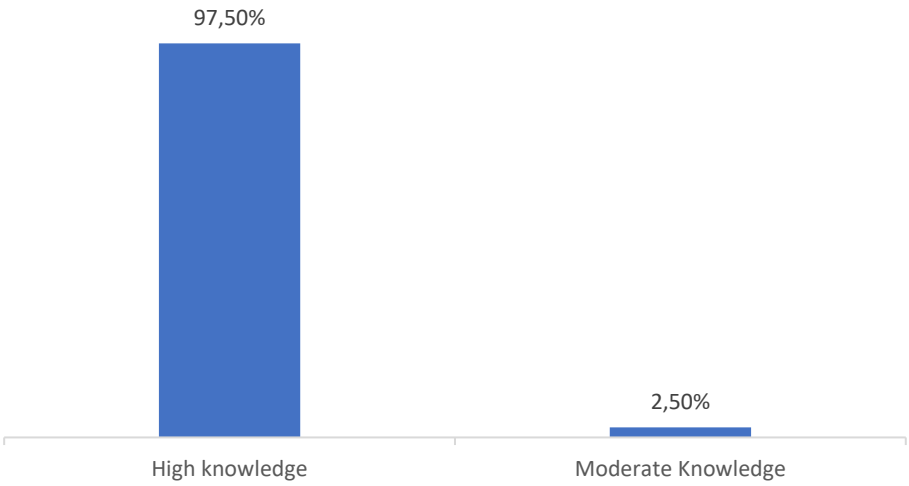


Fig 1: knowledge level of the farmers on mortality risk management practices

Information needs on mortality risk management practices

Data in Table 7 indicates that the major information needs of the respondents includes: effective risk management strategies (100.0%), mitigating the risks associated with disease outbreaks (100.0%), biosecurity measures to minimize disease transmission (100.0%), management and control parasite infestations (100.0%), ensuring the quality and safety of the feed provided to your birds (100.0%), preventing and management errors that can lead to higher mortality rates(100.0%), strategies to minimize the impact of extreme weather conditions on your poultry (98.3%), feed quality and formulations necessary (98.3%), identifying and assessing risks specific to your farm (96.7%), predator control measures to protect your birds (96.7%), disease surveillance systems important (81.7%), predator and wildlife management relevant (78.3%) and genetic management strategies to reduce vulnerability to diseases (75.0%) etc.

The majority (100%) of the farmers are interested in information on strategies to manage risks effectively in their poultry operations. This includes a wide range of risk factors, from disease control to biosecurity and more. All (100%) of the respondents are highly concerned on information regarding mitigating the risks associated with disease outbreaks in their poultry flocks. This is a critical aspect of poultry farming and the same 100% of respondents are interested in information on implementing biosecurity measures to minimize disease transmission within their poultry operations. Biosecurity is fundamental to prevent diseases from entering and spreading in the farm. The Food and Agriculture Organization (FAO) 2020),

supports and advises countries to improve their animal health surveillance and risk assessment capabilities by reviewing and publishing up-to-date disease information, including global disease situation updates, qualitative risk assessments for high-impact animal diseases, technical publications, and forecasting tools. These efforts help to improve the ability of countries to detect and respond to emerging diseases in poultry.

Overall, the data suggests that there is a high level of interest among the respondents in learning about various aspects of poultry management, including risk management, disease prevention, feed quality and safety, and predator control measures. There is also a significant interest in understanding how to prevent and manage management errors and in learning about genetic management strategies, although this interest is somewhat lower than for other topics. Knowledge of disease surveillance systems is also considered important by a majority of respondents. This information could be useful for developing educational programs or resources for poultry farmers to help them improve their operations and reduce risks.

Table 3: Information needs of the respondents.

Information needs	Frequency(f)	Percentage%
Effective risk management strategies for your poultry operation	60	100.0
Identifying and assessing risks specific to your farm	58	96.7
Mitigating the risks associated with disease outbreaks	60	100.0
Biosecurity measures to minimize disease transmission	60	100.0
Management and control parasite infestations	60	100.0
Predator control measures in protecting birds	58	96.7
Strategies to minimize the impact of extreme weather conditions in poultry farms	59	98.3
Ensuring the quality of feeds	60	100.0
Preventing and management of errors that can lead to higher mortality rates	60	100.0
Genetic management strategies to reduce vulnerability to diseases	45	75.0
Predator and wildlife management in poultry farms	47	78.3

Sources: Field survey 2023

Mortality risk management practices employed by the respondents

Data in Table 4 indicate mortality risk management practices of the respondents include; access to clean water and proper ventilation to prevent health issues ($\bar{x}$=4.87), monitor and control the feed quality of birds to reduce the risk of health issues ($\bar{x}$ = 4.82) biosecurity measures to prevent the spread of diseases ($\bar{x}$ = 4.80), ensure the safety of myself or workers and reduce the risk of accidents ($\bar{x}$ = 4.73), establishment of a network of suppliers and buyers to reduce supply chain risk ($\bar{x}$= 4.73), understanding of the regulatory environment governing poultry farming in my location" ($\bar{x}$=4.667), use of pest control measures to prevent the spread of pests and parasites in my poultry farm ($\bar{x}$ =4.65), cordial relationship with a veterinarian to

ensure the health and welfare of my birds ($\bar{x}$ =4.612) etc. The implication of the findings show that the mortality rate is low and they rarely will there be outbreak of disease in the farm. Mortality rate is an important indicator of the overall health and welfare of poultry flocks. High mortality rates can be a sign of poor management practices, inadequate nutrition, disease outbreaks, or other issues that negatively impact the health and well-being of the birds. Effective management practices can help to reduce mortality rates and improve the overall success of a poultry farming operation.

According to Jerson, (2020), Clean water and proper ventilation are essential for maintaining the health and welfare of poultry flocks. Access to clean water is important for preventing the spread of diseases and ensuring that birds are properly hydrated. Proper ventilation, on the other hand, helps to maintain good air quality by removing excess heat, moisture, and harmful gases such as ammonia and carbon dioxide from the poultry house. Ventilation is a key factor in poultry production facilities. Maintaining adequate temperature and aeration of the houses is essential to ensure animal welfare and economic performance of the farm. Ventilation helps to eliminate excess heat and humidity from the sheds where the birds are housed, generating comfort and welfare. Having a ventilation system and a controlled poultry environment provide some benefits such as correct balance of the gases that participate in the metabolism of the birds: good availability of oxygen breathed, and elimination of gases such as Carbon Dioxide CO2 and ammonia NH3. (Jerson, 2020). Overall, providing clean water and proper ventilation are important management practices in poultry farming that can help to prevent health issues, reduce mortality rates, and improve the overall success of a poultry farming operation. (Jerson, 2020)

Table 4: Mortality risk management practices

Risk management practices	Mean	Standard deviation
Biosecurity measures to prevent the spread of diseases	4.80	0.55
Monitor and control the feed quality of birds to reduce the risk of health issues	4.82	0.39
Contingency plan to deal with emergencies such as natural disaster	4.47	0.62
Use of pest control measures to prevent the spread of pests and parasites in my poultry farms	4.65	0.68
Records of poultry farming operations to track financial performance and identify areas for improvement	4.53	0.54
Cordial relationship with a veterinarian to ensure the health and welfare of birds	4.62	0.61
Diversification of my poultry farming operation by producing and processing birds for live sales and meat	4.33	0.86
Ensure the safety of myself or workers and reduce the risk of accidents	4.73	0.48
Management of the waste generated by poultry farming operation in an environmentally friendly way	4.57	0.53
Establishment of a network of suppliers and buyers to reduce supply chain risks	4.73	0.55
Ensure the safety of myself or workers and reduce the risk of accidents	4.73	0.48
Management of the waste generated by poultry farming operation in an environmentally friendly way	4.57	0.53
Establishment of a network of suppliers and buyers to reduce supply chain risks	4.73	0.55

Sources: Field survey 2023

Constraints to mortality risk management practices

Data in Table 5 below show constraints poultry farmers are faced with in mortality risk management practices; costly insurance coverages ($\bar{x}$=1.95), fluctuations in feed prices ($\bar{x}$=1.88), inadequate facilities and technologies ($\bar{x}$=1.78), limited market access ($\bar{x}$=1.583), costly and time-consuming regulatory measures ($\bar{x}$=1.53), cost of implementing biosecurity measures ($\bar{x}$=1.52), difficulty in securing loans ($\bar{x}$=1.50), high cost of transporting poultry birds and eggs to the market ($\bar{x}$=1.38), irregular visits of extension agents ($\bar{x}$=1.37), emergence of new diseases or invasive species of pests ($\bar{x}$=1.27), inadequate information on poultry management practices ($\bar{x}$=1.25) and inadequate land for expansion ($\bar{x}$=1.07). Costly insurance coverages ($\bar{x}$= 1.95). This finding implies that poultry farmers find insurance coverage to be costly, which can significantly impact their overall operational expenses. This is likely due to the various risks associated with poultry farming, such as disease outbreaks, natural disasters, and theft, which can make insurance premiums high. Additionally, the operational costs of running a poultry farm, including feed and veterinary care, can further strain a farmer's budget. Therefore, while insurance is crucial for mitigating risks and protecting their investment, the cost can be a significant burden for poultry farmers. Given these risks, it's understandable that poultry farmers find insurance coverage to be costly. While insurance is essential for risk management, the high cost can significantly impact their overall operational expenses. Fluctuations in feed prices ($\bar{x}$=1.88), high variability in feed prices is a significant concern for poultry farmers, as it affects their production costs and profitability and inadequate facilities and technologies ($\bar{x}$=1.78). The lack of modern facilities and technologies can hinder the efficiency and productivity of poultry farms, leading to financial challenges.

These challenges have made it difficult for the farmers to expand their farms. The implication of this is that, it increases in costly insurance coverages and fluctuations in feed prices were inhibiting the growth of poultry production in the study area. Furthermore, Table 5 also shows the standard deviation which shows that the standard deviation values reflect the degree of consensus or variation among poultry farmers' perceptions of specific challenges. Lower standard deviations (e.g., for feed prices, insurance costs, and market access) indicate that most farmers generally agree on the severity of these challenges. In contrast, higher standard deviations (e.g., for irregular visits of extension agents and inadequate land for expansion) suggest more diversity in opinions and experiences among farmers regarding these challenges. Factors such as regional differences, individual circumstances, and the nature of the challenges themselves influence the level of variation in responses.

Table 5: Constraints to mortality risk management practices

Constraints to risk management practices	Mean	Std. Deviation
Difficulty in securing loans	1.50*	0.79
Irregular visits of extension agents	1.37*	0.88
Inadequate veterinary services	0.98	0.83
Fluctuations in feed prices	1.88*	0.37
Costly and time-consuming regulatory measures	1.53*	0.75
Cost of implementing biosecurity measures	1.52*	0.75
Inadequate information on poultry management practices	1.25	0.86
Inadequate land for expansion	1.07	0.84
Labor shortages	0.85	0.88
Inadequate facilities and technologies	1.78*	0.72
Costly insurance coverages	1.95*	0.50
Limited market access	1.58*	0.56
Emergence of new diseases or invasive species of pest	1.27	0.70
High cost of transporting poultry birds and eggs to the market	1.38	0.67
Unavailability of drugs for the treatment of some diseases	0.85	0.73
Predator	0.73	0.86
Theft	0.43	0.65

Source: Field survey, 2023

Conclusion and recommendation

This study examined mortality risk management practices among poultry farmers in Enugu State, Nigeria, highlighting the various strategies employed to mitigate losses due to poultry mortality. The findings reveal that while many farmers are aware of the risks associated with poultry farming, their management practices vary significantly in effectiveness due to factors such as access to veterinary services, level of education, and financial capacity. Preventive measures such as proper hygiene, vaccination, and biosecurity were commonly adopted, though often inconsistently. Financial constraints and limited access to technical support were among the key challenges limiting the adoption of more effective risk management strategies. To enhance poultry productivity and reduce mortality, it is essential to improve access to veterinary services, provide targeted training programs for farmers, and facilitate access to affordable insurance and credit facilities. Effective mortality risk management is critical to sustaining poultry production. Stakeholders including government agencies, agricultural extension services, and non-governmental organizations must work collaboratively to support farmers to reduce losses and ensure long-term viability in the poultry sector in Enugu State. Therefore, the study recommends that Enugu State government and non-governmental organizations should support poultry farmers in making available affordable insurance policies that can help them to mitigate against mortality risk in their farms.

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ASSESSMENT OF LIFE CYCLE EMBODIED ENERGY AND RELATED CO_2 EMISSIONS, A CASE STUDY OF HISTORIC COLLEGE BUILDING IN GAZİANTEP

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ABSTRACT

The building sector conduce remarkably to global warming, liable for 35% of global energy use and 38% of related CO_2 emissions. In this regard, assessment of environmental impacts of buildings during the construction, use and destruction phase is important issue for ecological sustainability. This paper estimates the life cycle embodied energy consumption (LCEEC) and related embodied CO_2 emissions of a historic college building (B-1) dates back to 1875, a contemporary building (B-2) erected with the most recent construction materials with compatible floor plans of the historic college building and the historic college building after that the structural strengthening and restoration (B-3) by utilizing tangible documents acquired from the building site. The findings of the study demonstrated that LCEEC values of B-1, B-2 and B-3 are found to be 4039.01, 2969 and 5709 GJ, respectively. Embodied CO_2 emissions pertinent to construction of the B-1, B-2 and B-3 are calculated to be 215.85, 281.12 and 347.94 tCO_2, respectively. Via implementing current practices, the structural strengthening and restoration of the historic college building enhances about 41.36% of LCEEC as well 61.2% of embodied CO_2 emissions. Structural strengthening and restoration of historic structures should be carried out via implementing convenient practices respecting the heritage conservation policies, ecology and energy.

Keywords: Global warming**,** Ecological sustainability, Life cycle assessment, Embodied energy, CO_2 emissions

1. Introduction

In previous decades, buildings and construction sector have become a key element tending to diminish global greenhouse emissions. The construction sector is liable for remarkable energy use globally that cause greenhouse emissions in conjunction with the diminution of energy supplies. The use of fossil resources as the primary source for energy throughout the world further aggravate this issue. All fossil resources release CO_2 to the atmosphere as burned. The CO_2 facilitates trap heat within the atmosphere, a primary contributant factor to the potential global warming (Goudie, 2013). The former decade was declared to be one of the hottest period and CO_2 concentrations have currently attained over 401 ppm (parts per million) (Tans, 2014) , that is regarded to be remarkably higher than allowable limit of 350 ppm for atmospheric CO_2 (Rauf and Crawford, 2015) . In the last age, the population of world has raised expeditiously accompanied by increment in per capita energy demand and life expectancy (Smil, 2011). It is foreseen that this trend will proceed. Therefore it is crucial that energy demand within the buildings and construction sector is addressed in order to prevent further deterioration of the ecology.

Heritage Buildings (HBs) stand for a pecicular building sample, and these structures are dependent upon legal conservation provisions because of their tremendous importance. The favourable effects of reusing HBs against to construction of new buildings are often considered in respect of design, cultural and economic aspects. If such considerations are broadened to involve ecological impact, one must furthermore tackle the issue of Embodied Energy (EE) . The EE is the summation of whole the energy needed to extract, process, transfer and set up the materials required to form a building (Jackson, 2005).

A number of studies have been presented in order for surveying the ecological impacts of buildings and its constitutive materials. But, most of the investigators paid attention to recently constructed structures. There is a gap of knowledge in existent literature about the structural strengthening and restoration practices on the LCEEC and related embodied CO_2 emissions of HBs. The target of this research is to examine the LCEEC and related emissions of a historic building, match the findings with re-construction project scenario of the historic structure, and show the effects of structural strengthening and restoration of throughout a lifespan period of 50 year.

2. Materials and Methods

2.1. Life Cycle Analysis (LCA) Methodology

LCA methodology is used to determine the environmental impacts of a process or product throughout its lifespan. LCA practice quantify entire the supply as inputs, comprehending energy, materials as well water, and ecological burdens involving emissions and wastes of a structure throughout differing stages of the life cycle. This methodology can be formulized by the subsequent arithmetic equation:

$$I = I_{Extraction} + I_{Manufacture} + I_{Onsite} + I_{Operation} + I_{Demolition} + I_{Recycling} + I_{Disposal} \quad (1)$$

in which I symbolizes to life cycle ecological effect, and I_j symbolizes to ecological effects of jth building phase.

Three basic category of studies are present dealing with the ecological effects of structures. The initial category of studies is LCA that centers on the whole ecological effects of structures within their entire lifespan. The second category of studies is Life Cycle Energy Assessment (LCEA), which is a valuation of the energy consumption over distinct phases of a buildings' lifespan, expressed as primary energy derived from nature furthermore secondary energy as tangibly depleted energy (Fay et al., 2000; Chau et al., 2015; Atmaca et al., 2021) The latter category is the Life Cycle Carbon Emissions Assessments ($LCCO_2A$), the main target of which is to valuate the CO_2 outputs throughout the entire lifespan of a structure (Chau et al., 2015).

2.2. LCEA and $LCCO_2A$ Methodology

LCEA approach can be stated as a simplified form of LCA that solely targets the assessment of energy intakes for distinct stages of the life cycle. The energy needed for production (embodied energy), use (operating energy), and destruction phases constitutes the boundary of the system. Production phase comprises procurement and conveyance of building materials as well maintenance activity of the buildings. Use phase involves the energy required for space heating as well cooling, ventilation, hot water, lighting and operating electrical devices in the building. Lastly, destruction phase comprises demolition of the structure and conveyance of deconstructed debris to recycling factory or landfill areas. LCEA approach can be implemented using primary or else secondary energy. Primary source of energy is derived from nature (e.g.natural gas), whereas actually consumed source of energy is secondary energy (e.g.electricity) (Chau et al., 2015).

In a mathematical form, the terms 'I's in Eqn. (1) are interchanged by 'E's to obtain Eqn. (2) as indicated in the subsequent equation:

$$E= \quad E = E_{Extraction} + E_{Manufacture} + E_{Onsite} + E_{Operation} + E_{Demolition} + E_{Recycling} + E_{Dis} \qquad (2)$$

in which E symbolizes to the total energy depleted within the whole life cycle of a structure, and E_j symbolizes to the energy depleted over jth building phase.

The cumulative carbon equivalent (CE) emissions generated at discrete steps of the life cycle of a structure form the domain of $LCCO_2A$. The value of life cycle carbon outputs can be estimated by interchanging the terms I' s in Eqn. (1) with 'CO_2' and it can be obtained numerically from the Eqn. (3):

$$CO_2 = CO_{2Extraction} + CO_{2Manufacture} + CO_{2Onsite} + CO_{2Operation} + CO_{2Demolition} + CO_{2Recycling} + CO_{2Disposal} \qquad (3)$$

in which CO_2 symbolizes to the CO_2 outputs of a structure over the whole life cycle, CO_{2j} symbolizes to the CO_2 outputs over the jth building phase.

Three practices are utilized in life cycle approach: process analysis, input-output (I - O) analysis, as well hybrid analysis. Preference of the basic analysis methodology, controls the precision of life cycle approach. Process Analysis is a bottom-up practice which just comprise processes over the limits of the product system being evaluated. But, ecological effects,

affiliated with inputs and outputs, which are placed away from the system limits are out of the framework of this methodology. This procedure is generally typified by the 'truncation error', which is involved with the elimination of stages omitted in the upstream levels of the framework (Lenzen, 2000).

Embodied energy incorporate two principal components (Chau et al., 2015):

- Initial embodied energy: the overall energy that encompasses material extraction and manufacturing, thereafter energy required to carriage of the material to field of construction.
- Recurrent embodied energy: the overall energy that is needed for replacement or refurbishment of building.

In this study, in order for estimating LCEEC and related CO_2 emissions, ICE (Inventory of Carbon and Energy) Version 3.0 is utilized (Jones and Hammond, 2019). For a vast number of materials, the ICE database contains estimates of EE, carbon as well GHG (quantified in grams of CO_2 equivalent, g CO_2eq.). The LCEEC of the structures have been estimated by counting recurrent embodied energy. In order to generate architectural plans of the building models Autodesk Revit BIM software is used. Material quantities of the building models were collected from the BIM software tool.

2.3. Suppositions and Uncertainities

LCEEC and related CO_2 emissions analysis of structures encompass several simplifications and suppositions associated with the kinds of building materials applicated. Important uncertainties prevail pertinent to energy depletion and related CO_2 emissions by reason of the place and the location of the buildings, the constituent materials of structures and processes for material production. Slight discrepancies and variations in any of such factors can alter the outcomes of this survey. The following suppositions were considered within the calculations

- It was assumed that manufacturing of entire final products carried out within Gaziantep city, supposing that the products are conveyed inside of a 40 km radius.

- Energy intensities, construction materials and standard construction procedures were supposed to be same throughout the next 50 years.

- So as to compare the findings, the lifecycle period of the studied buildings was supposed to be 50 years.

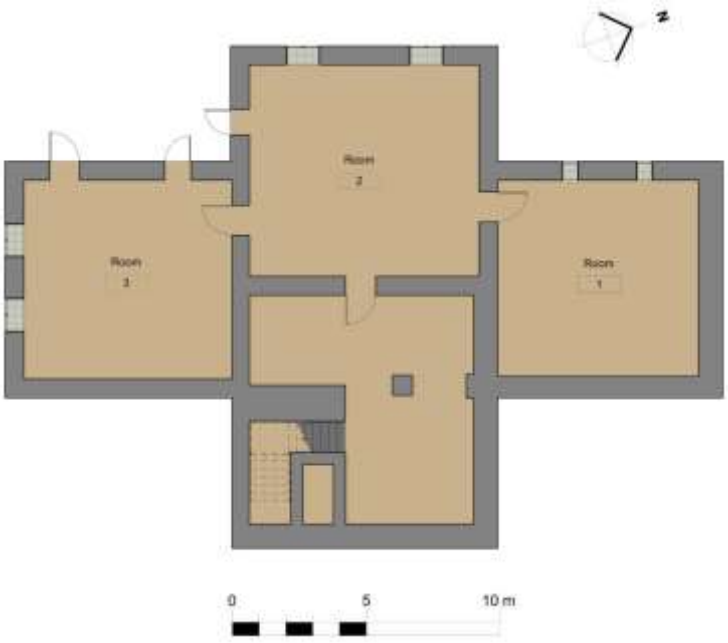
- The service lives were supposed to be identical for both studied buildings and building materials.

3. Case Study

3.1. The Historic Building (B-1)

The historic building is located in the city of Gaziantep that takes place in the southeast part of Turkey. The city had a multi-religious and multiethnic fabric. In the 19th age, missionary strategies provided to its multi-layered fabric. As well as Latin Catholics, American Congregationalists, and some Anglicans inhabited in the city; their religious, instructional, and healthcare facility structures enabled diversity in built environment of the city. The surveyed historic college building building is one of the remained buildings which was built by the American Board in 1875 (Babanınoğlu, 2020). The Central Turkey College was in the form of

campus that involve several structures. But, as a consequence of damaging fire happened in 1890 nearly 70% of the structures inside the campus was devastated (Güllü, 2009). The historic building includes three floors (basement, ground, as well first floor) and eight rooms. The cumulative floor area of B-1 is 1008.16 m^2. B-1 was constructed with load bearing masonry wall that is made up of limestone blocks and timber floor. Figure 1 demonstrates the 1/100 scaled floor plans of the B-1. Exact details of the B-1 are given in Table 1. Figure 2 shows dated photo of B-1.



Basement floor plan



Ground floor plan

Figure 1. Floor plans of B-1



1 st floor plan

Figure 1. (continued)

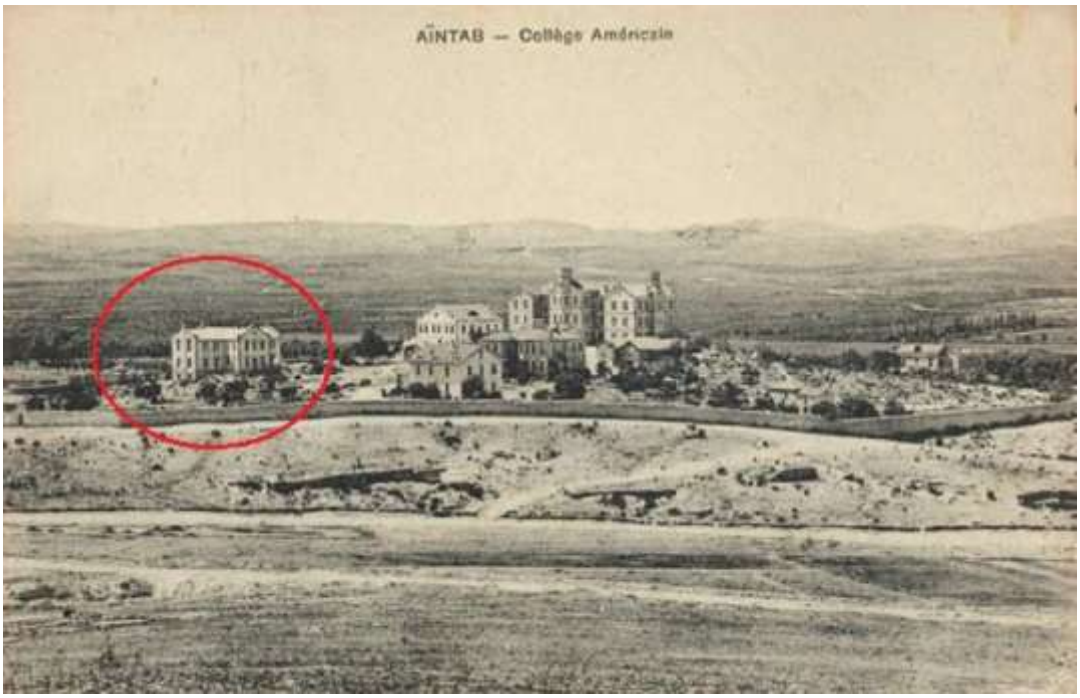


Figure 2. Photo of B-1 (Source: https://www.levantineheritage.com/antep.htm)

3.2. Reconstruction Scenario (B-2)

In B-2, the reconstruction scenario has been analysed by the usage of novel structural elements as well as materials. The B-2 is assessed to be redesigned by Reinforced Concrete (RC) framed structure which has modelled with high strength concrete of 35 Mpa and steel rebar grade of S420. Exterior and partition wall constructions of B-2 have been formed with aerated concrete blocks in lieu of masonry wall. The façade of the building has been designed by conforming to the obligatory standard of TS825 (Thermal Insulation Requirements for Buildings). In order for preventing moisture and infusion of water, bitumen is used at the foundation section of the building. For B-2 case, the precise quantities of concrete and structural steel have been computed by a structural analysis program (ideCAD Structural Analysis v 10.17) conforming the requirements of Turkish Building Earthquake Code of 2018. Exact details of the B-2 are given in Table 1. Figure 3 shows floor plans of the B-2.

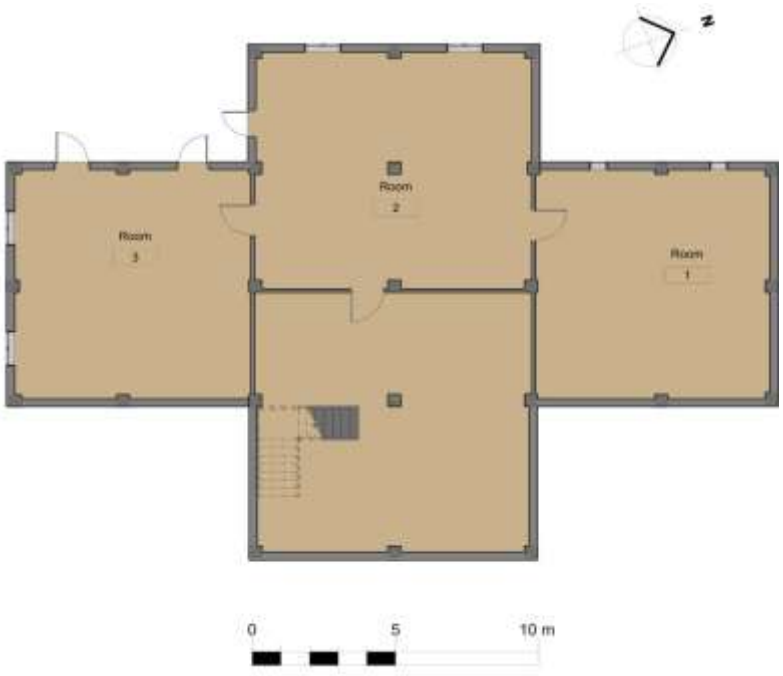
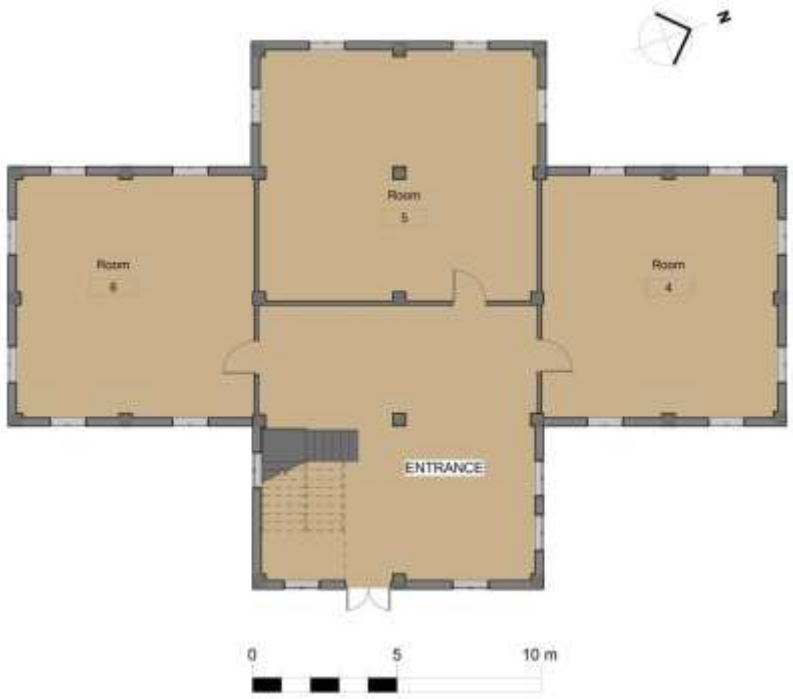
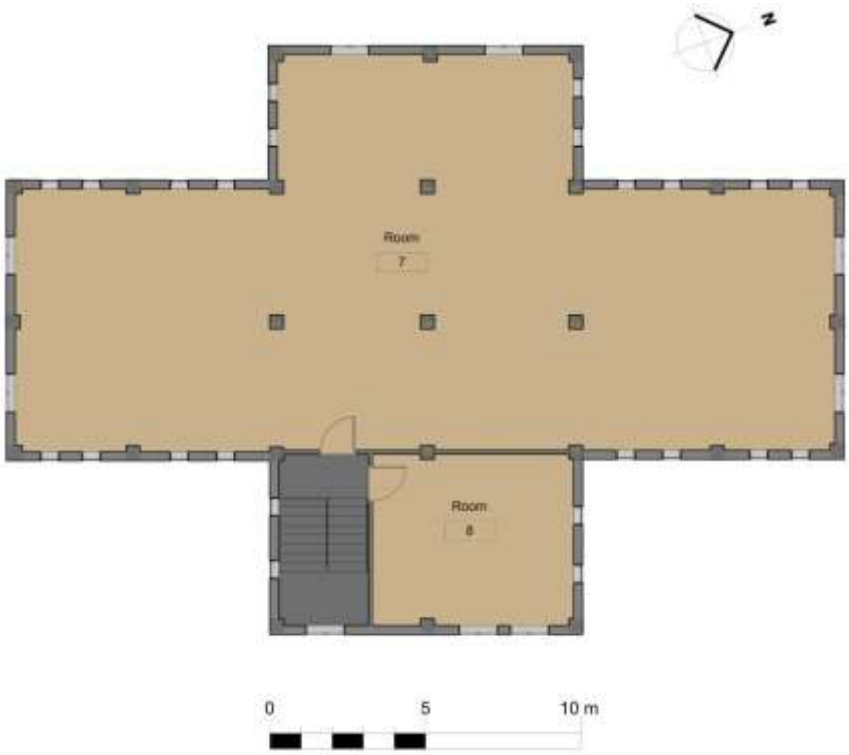


Figure 3. Basement floor plan



Ground floor plan



1 st floor plan

Figure 3. (continued)

3.3. Structural Strengthening and Restoration Case (B-3)

In recent years, B-1 has been seismically upgraded with steel frame to sustain its structural safety. Also, windows were renovated by double glazed (6 mm thickness) wooden windows. Roof of the B-1 was reconstructed with timber roof truss that has a standard layer of bitumen and glass wool insulation (8 cm thickness). In order to survey effect of thermal insulation on energy use, it has been presumed that external walls of the structure had been insulated with 3 cm thick rock wool together with overlaying by plaster layer (1.5 cm thickness). The quantities of building materials pertinent to structural strengthening and restoration case was collected from Şahinbey Municipality. Exact details of the B-3 are given in Table 1. Figure 4 demonstrates photos of the B-3.

Table 1. Specifications of B-1, B-2, and B-3

Specifications	**B-1**	**B-2**	**B-3**
Number of floor	3	3	3
Base area (m^2)	340.33	340.33	340.33
Gross floor area (m^2)	1008.16	1008.16	1008.16
Total building height	10.33 m	10.33 m	10.33 m
Floor elevation	2.93 m for basement floor 3.70 m for ground floor 3.70 m for 1 st floor	2.93 m for basement floor 3.70 m for ground floor 3.70 m for 1 st floor	2.93 m for basement floor 3.70 m for ground floor 3.70 m for 1 st floor
Foundation	20 cm compacted crushed stone	50 cm raft foundation Bitumen 10 cm lean concrete	20 cm crushed stone
Internal wall	Limestone block wall (thickness of 45- 60 cm)	10 cm aerated concrete block	Limestone block wall (thickness of 45- 60 cm)
External wall	Limestone block wall (thickness of 60- 90 cm)	20 cm aerated concrete block	Limestone block wall (thickness of 60- 90 cm) 3 cm rockwool insulation 1.5 cm of plaster inside
Windows	Single glazed (3 mm thickness) windows having wood frame	Double glazed (3 mm glass + 12.7 mm cavity + 3 mm glass) windows having aluminum frame	Double glazed (3 mm glass + 12.7 mm cavity + 3 mm glass) windows having wood frame
Roof	Roofing tile Timber roof trusses	Roofing tile Bitumen Timber roof trusses	Roofing tile Bitumen Timber roof trusses 8 cm thickness glass wool
Floor	Timber floor slab (25 cm thickness)	Reinforced concrete slab (15 cm thickness) 2 cm marble tile	Timber floor slab (25 cm thickness)
Doors	Wooden doors	Wooden doors	Wooden doors
HVAC system	Central VAV, HW heat, chiller 5.96 COP, boilers 84.5 eff.	Central VAV, HW heat, chiller 5.96 COP, boilers 84.5 eff.	Central VAV, HW heat, chiller 5.96 COP, boilers 84.5 eff.



Front aspect of B-3



Side aspect of B-3

Figure 4. Photos of B-3



Interior aspect of B-3



Interior aspect of B-3

Figure 4. (continued)

4. Findings and Discussion

Table 2,3 and 4 demonstrates the EE and related CO_2 values as well the quantities of construction materials relevant to B-1, B-2 and B-3, respectively.

Table 2. EE, CO_2 and construction material quantities of each section of B-1

No.	*Sections*	*Materials (kg)*	*Amount (kg)*	*EE (MJ/kg)*	*CO_2 ($kgCO_2/kg$)*	*Total EE (MJ)*	*Total CO_2 (kg CO_2)*
1	Foundation	Gravel	184,951.9	0.083	0.0048	15,351	887.7
2	Wall	Limestone block	1,828,612.5	1.5	0.09	2,742,918	164,575
3	Floors	Timber	82,376	10	0.31	823,760	25,536
		Limestone tile for basement floor	92,475.9	1.5	0.09	138,713	8322
		Limestone block for stairs	30,607.50	1.5	0.09	45,911	2754
4	Roof	Roof tile	15,132.60	6.5	0.48	98,361	7263
5	Others	Timber	13,480	10	0.31	134,800	4178
		Wood doors	872	11	0.7	9,592	610
		Iron railing	326.2	25	1.91	8,155	623
6	Windows	Wood window unit (with single glazed glass)	75	286	14.6	21,450	1095
					TOTAL	*4,039,011*	*215,847*

Table 3. EE, CO_2 and construction material quantities of each section of B-2.

No.	**Sections**	**Materials (kg)**	**Amount (kg)**	**EE (MJ/kg)**	**CO_2 ($kgCO_2/kg$)**	**Total EE (MJ)**	**Total CO_2 (kg CO_2)**
1	Foundation	Concrete	491,408.6	0.88	0.13	432,439.5	64,865.94
		Steel	14,822	21.6	1.9	320,155.2	28,161.8
		Bitumen	1,234	50	0.43	61,700	530.62
2	Wall	Aerated concrete	83,438.8	0.83	0.1	69,254.2	8,343.88
		Painting	478.9	70	2.91	33,523	1,393.6
		Plaster	47,938.5	1.8	0.13	86,289	6,232.01
3	Floors	Concrete	599,334.3	0.88	0.13	527,414.1	79,112.13
		Steel	24,325.7	21.60	1.9	525,435.1	46,218.83
4	Flooring	Marble tiles	51,161.1	3.33	0.21	170,366.4	10,743,83
		Plaster	21,813.1	1.8	0.13	39,263.58	2,835.7
		Painting	335.5	70	2.91	23,485	976.31
5	Roof	Roof tiles	15,132.6	6.5	0.48	98,361.9	7,263.65
		Timber	13,480	10	0.31	134,800	4,178.8
		Bitumen	1175.3	51	0.43	59,940.3	505.38
6	Others	Wood doors	992	11	0.7	10,912	694.4
		PVC doors	180.6	77.2	2.61	13,942.32	471.37
		Aluminium railing	113.3	214	12.5	24,246.2	1416.25

7	Windows	Aluminium window unit (with double glazed glass)	75	4,500	229	337,500	17,175
					TOTAL	2,969,028	281,119

Table 4. EE, CO_2 and construction material quantities of each section of B-3

Section	Material	Amount (kg)	EE (MJ/kg)	CO_2 ($kgCO_2/kg$)	Total EE (MJ)	Total CO_2 (kg CO_2)
Foundation	Gravel	184,951.9	0.083	0.0048	15,351	887.7
Wall	Limestone block	1,828,612.5	1.5	0.09	2,742,918.75	164,575.13
	Rockwool	2,666.4	16.8	1.05	44,795.52	2,799.72
	Plaster	28,070.7	1.8	0.13	50,527.26	3,649.19
Floors	Timber	82,376	10	0.31	823,760	25,536.56
	Limestone tile for basement	92,475.9	1.5	0.09	138,713.85	8,322.83
	Limestone block for stairs	30,607.5	1.5	0.09	45,911.25	2,754.68
	Steel	63,280	21.6	1.9	1,366,848	120,232
Roof	Roof Tile	15,132.6	6.5	0.48	98,361.9	7,263.65
	Timber	13,480.6	10	0.31	134,800	4,178.8
	Bitumen	1,175.3	50	0.43	58,765	505.38
	Glass wool	534.9	28	1.35	14,977.2	722.12
Others	Timber	13,480	10	0.31	134,800	4,178.8
	Wood doors	872	11	0.7	9,592	610.4
	Iron railing	326.2	25	1.91	8,155	623.04
Windows	Wood window unit (with double glazed glass)	75	286	14.6	21,450	1,095
					5,709,726	347,935

The findings of our study showed that the B-1 has a total EE of 4039.01 GJ. The total embodied carbon associated with construction of the B-1 is 215.85 tCO_2. Masonry wall (72% of EE) and wood (24% of EE) are the main building materials referring to EE usage for the B-1. It is determined that masonry wall (81%) and wood (14%) produce the foremost contribution with respect to CO_2 outputs.

The B-2 has a total EE of 2969 GJ. The total embodied carbon associated with construction of the B-2 is 281.12 tCO_2. Concrete (29% of EE) and steel reinforcement (26% of EE) are the main building materials referring to EE usage for the B-2. Concrete and steel reinforcement produce the foremost contribution with respect to CO_2 outputs with a reciprocal proportion of 48%, and 25%, respectively.

The B-3 has a total EE of 5709 GJ. The total embodied carbon associated with construction of the B-3 is 347.94 tCO_2. It is understood that masonry wall and steel are the main building materials referring to EE usage with a corresponding contribution of 47% and 28%,

respectively. It is essential to declare that the structural strengthening and restoration of B-1 has raised about 41.36% of LCEEC as well as 61.2% of related CO_2 emissions of the building.

Figures 5, 6, and 7 demonstrates the EE shares of the construction materials for B-1, B-2 and B-3 respectively.

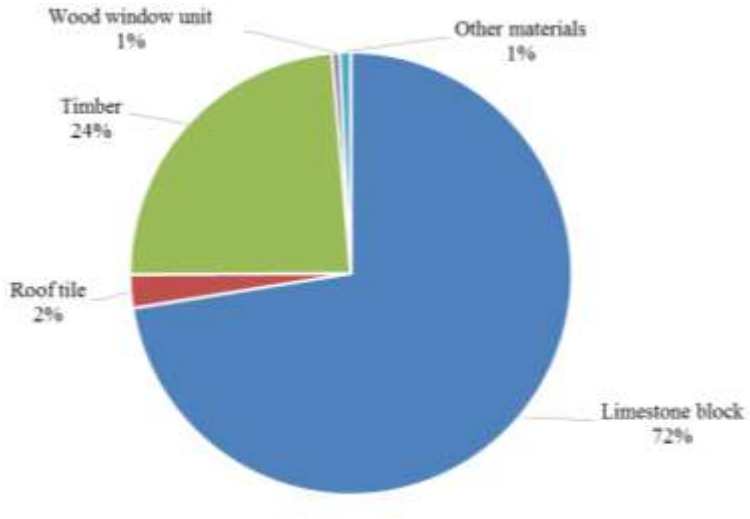


Figure 5. EE shares of building materials for B-1

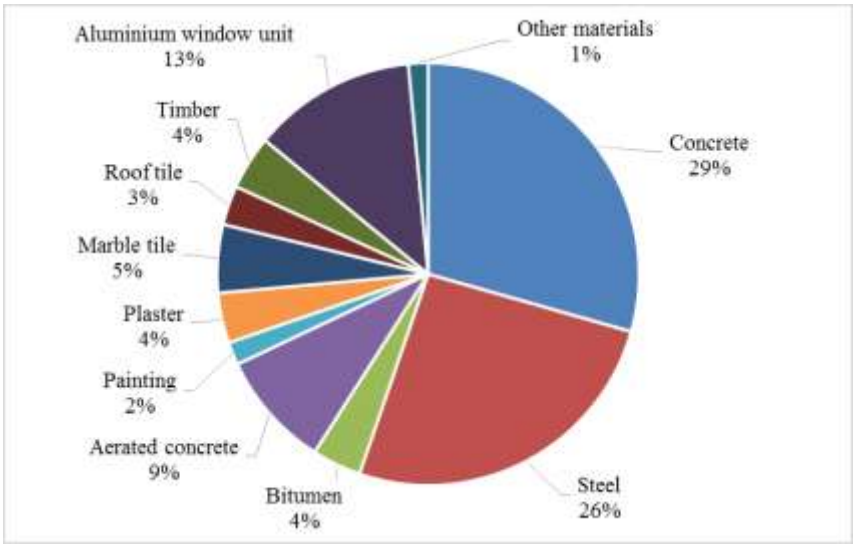


Figure 6. EE shares of building materials for B-2

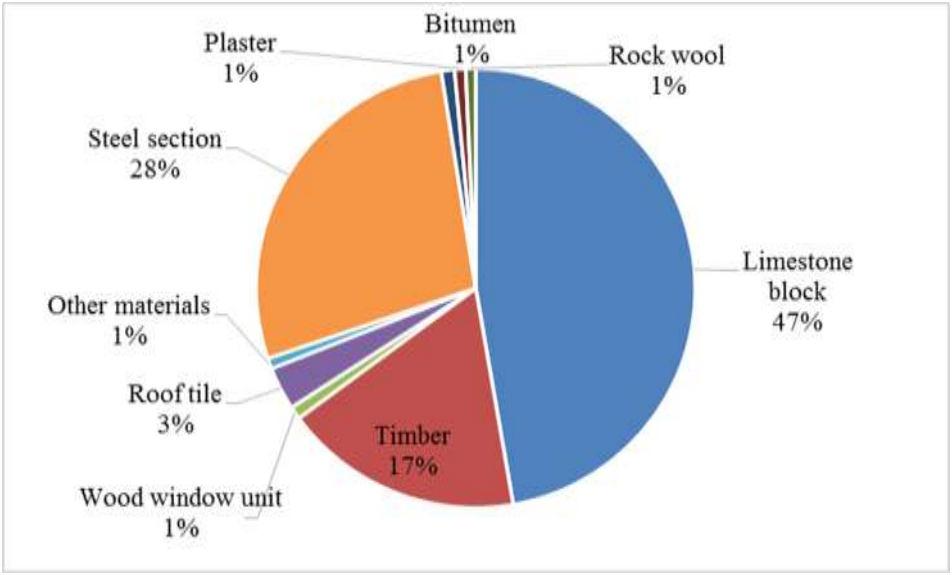


Figure 7 EE shares of building materials for B-3

5. Conclusion and Recommendations

In this survey, LCEEC and related CO_2 emissions of a historic college building (B-1), rebuilt scenario of a contemporary building (B-2) and structural strengthening and restoration of heritage building (B-3) in Gaziantep, Turkey are examined thoroughly. It is concluded that historic college building has 36.04% greater LCEEC with respect to the contemporary building. However, the contemporary building has 30.24% higher embodied CO_2 emissions than the historic college building. Via implementing current practices, the structural strengthening and restoration of the historic college building enhances about 41.36% of LCEEC as well 61.2% of embodied CO_2 emissions.

Even though operating energy of buildings is expressed as the basis of sustainability in building energy performance regulations, EE and related CO_2 emissions will become more crucial as operating energy depletion is reduced.

During the construction of buildings, substantial amount of construction materials that have higher embodied CO_2 are practiced (for instance steel rebar, concrete, dye and insulation materials). The choice of materials for construction has a direct impact on EE and related CO_2 emissions. The EE of a wood window with double pane is 0.49 GJ/kg, whilst this value is 5.47 GJ/kg for a aluminium window with double pane.

Sustainable practices for structural strengthening and restoration of HBs are crucial to alleviate the LCEEC and related CO_2 outputs. The determinations related with LCEEC and related embodied CO_2 emissions acquired from this investigation are a breakthrough for heritage building stock in Turkey. Future investigations should pay attention to analysis of proper multi-objective retrofit practices and techniques for historic structures.

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AROMATIC POTENTIALS OF *Mentha longifolia* subsp. *longifolia* L. ESSENTIAL OILS: INSIGHTS FROM GC-MS PROFILING

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ABSTRACT

This study aims to evaluate the potential industrial and pharmacological applications of *Mentha longifolia* subsp. *longifolia* L. through a detailed analysis of its essential oil composition and comparative review of the literature. The taxon *Mentha longifolia* subsp. *longifolia* is a member of the Lamiaceae family, known for its aromatic and medicinal properties. In Turkey, the *Mentha* genus is represented by 11 distinct species, among which this subspecies is particularly notable for its essential oil content.

The GC-MS analysis of the sample conducted in this study identified 87 compounds, with *Eucalyptol* (28.89%), *Menthone* (17.59%), and *Thymol* (10.60%) being the major constituents. These components have been highlighted in literature for their significant antimicrobial and antioxidant activities.

Essential oils from *Mentha longifolia* have been noted for their dual use in food—both as flavoring agents and natural preservatives, owing to their antimicrobial properties. The menthol content has shown documented soothing effects on the digestive system. Furthermore, thanks to its high content of terpenes and natural aroma compounds, this essential oil is utilized in chewing gum, confectionery, and beverages.

Due to the presence of antioxidant compounds, the oil is also favored in anti-aging cosmetic products, where it neutralizes free radicals effectively. The GC-MS findings, along with existing literature, underscore the strong pharmacological potential of *Mentha longifolia* subsp. *longifolia*. These insights provide a scientific foundation for further exploration of its use in pharmaceutical and cosmetic industries.

Keywords*: Essential oil, Ethnobotany, Mentha*

1.Introduction

Medicinal and aromatic plants have been known for centuries as natural resources with a wide range of applications in both traditional medicine and modern pharmaceutical research (Yıldız et al., 2019). These plants' essential oils, thanks to their rich chemical compositions, are utilized in numerous fields such as the food, cosmetic, and pharmaceutical industries (Çelik et al., 2020). Monoterpenes, sesquiterpenes, and other phytochemical compounds found in these essential oils draw significant attention due to their antimicrobial, antifungal, antioxidant, and anti-inflammatory properties (Kaya et al., 2021). The taxon *Mentha longifolia* subsp. *longifolia* is a member of the Lamiaceae family, known for its aromatic and medicinal properties (Davis, 1982). In Turkey, the *Mentha* genus is represented by 11 distinct species, among which this subspecies is particularly notable for its essential oil content. It usually grows naturally along stream banks, wetlands and thickets. This taxon, which is widespread in the flora of Turkey, can exist in different climatic and soil conditions with its strong adaptability (Baser et. al., 1999).

Mentha longifolia subsp. longifolia L. is defined as one of the richest species of the Lamiaceae family in terms of essential oil and has been used in traditional medicine for a long time. This subspecies is widely grown especially in the Middle East and Mediterranean geography and attracts attention in terms of pharmacological and industrial applications thanks to the phytochemical compounds it contains (Yousefian & Esmaeili, 2023; Patonay et. al., 2021).

In addition, like other species belonging to the Lamiaceae family, Mentha longifolia has developed adaptation against environmental stresses through essential oils and this adaptation contributes to the chemotype richness of the plant (Patonay et al., 2021). This species, which has a natural distribution especially in the flora of Turkey, is also used by local people in traditional herbal treatments for stomach ailments, respiratory diseases and antiseptic purposes (Singh & Pandey, 2018).

The aim of this study is to analyse the essential oil composition of *Mentha longifolia* subsp. *longifolia* in detail and to establish a scientific basis for the industrial and therapeutic potential of its bioactive compounds.

2. Materials and Methods

2.1. Collection of the Plant Material

The plant material utilized in this study was gathered from Bingöl province. It was collected from its natural habitat during May–June, which corresponds to the peak flowering period, and subsequently dried in the shade. Plant specimens were preserved at Firat University.

2.2. Isolation of the Essential Oil

Essential oils were obtained from the aboveground parts (100 g) of the collected plants using the Clevenger apparatus. Essential oils were obtained after 3-4 hours of distillation by hydrodistillation and no oil was obtained from some samples.

2.3. Gas Chromatography–Mass Spectrometry (GC-MS) and FID Analysis

The EO was analyzed using HP 6890 GC equipped with an FID detector. An HP-5 MS capillary column (30 m × 0.25 mm i.d., film thickness 0.25 μm) was used. The column and the analysis

conditions were the same as in Gas Chromatography-Mass Spectrometry (GC/MS). The percentage composition of the EO was computed from Gas Chromatography-Flame Ionization Detection (GC/FID) peak areas without correction factors. Chromatographic processes were performed at Fırat University Plant Products and Biotechnology Res. Lab. (BUBAL), using Hewlett Packard system, HP-Agilent 5973 N GC-FID and GC-MS (Gas ChromatographyMass Spectrometer) 6890 GC system. Helium was used as DB-5 MS column and carrier gas; Injector temperature 250°C, split flow rate 1 ml/min. The GC oven temperature was kept at 60°C for 2 min and programmed to 150°C at a rate of 10°C/min and then kept constant at 150°C for 15 min to 240°C at a rate of 5°C/min. The characterization of the components in essential oils was done using electronic libraries (WILEY, NIST and Essential oil library) (Wiley, 1989; NIST, 2002).

Table 1. The essential oil composition of *Mentha longifolia* subsp. *longifolia*

No	R.T.	Compounds	Area	%
1.	5.09	Cyclohexane, methyl	1517778	0.05
2.	6.41	Heptanal	1388351	0.04
3.	7.48	1,3-Cyclohexadiene,1-methyl-4-(1-methylethyl)-	818644	0.02
4.	7.68	□-Pinene	34470986	1.15
5.	8.03	Toluene	1624690	0.05
6.	8.25	Camphene	1158465	0.03
7.	9.057	Bicyclo[3.1.0]hexane,4-methylene-1	66082796	2.22
8.	9.244	Bicyclo[3.1.1]heptane,6,6-dimethyl-2-methylene	103027546	3.46
9.	9.458	5-Hepten-2-one, 6-methyl	1799196	0.06
10.	9.615	□-Myrcene	49765772	1.67
11.	9.926	Phenol, 2-methoxy-	50571284	1.69
12.	10.12	Piperidine	1665295	0.05
13.	10.41	Cyclohexaneethanol	949691	0.05
14.	10.59	+ 4-Carene	2088940	0.07
15.	10.88	Benzene, 1-methyl-2-(1-methylethyl)	2776210	0.09
16.	11.27	**Eucalyptol**	949203985	**28.89**
17.	11.53	Benzeneacetaldehyde	3025611	0.10
18.	11.60	Benzeneacetamide	1102762	0.03
19.	12.01	1,4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)	4293415	0.14
20.	12.19	□-Caryophyllene	868816	0.02

21.	12.45	1-Heptanol	6548026	0.22
22.	12.92	Cyclohexane, methyl	1986648	0.06
23.	13.09	Cyclopropanamine, 2-phenyl-, trans	969462	0.03
24.	13.34	1,6-Octadien-3-ol, 3,7-dimethyl	2312339	0.07
25.	13.41	Cyclohexanol, 2-methyl-5-(1-methylethenyl)	5630535	0.18
26.	13.57	Nonanal	922916	0.03
27.	13.63	Butanoic acid, 3-methyl-, 3-methylbutyl ester	1541981	0.05
28.	14.07	Phosphoric acid, trimethyl ester	22657658	0.76
29.	14.32	Formic acid, octyl ester	1677989	0.05
30.	14.54	Phenol, 2-methoxy-4-methyl	2862541	0.09
31.	14.73	Benzene, butyl	7342892	0.24
32.	14.93	2-Cyclohexen-1-ol,2-methyl-5-(1-methylethenyl)	2472589	0.08
33.	15.47	Phenol, 3-methyl	2861735	0.09
34.	15.73	1-Nonanol	36723147	1.23
35.	15.91	Borneol	1702516	0.05
36.	16.04	Camphor	7022570	0.23
37.	16.16	2,6-Octadienal, 3,7-dimethyl-	2728987	0.09
38.	16.55	**trans-□□Terpinyl butanoate**	148541808	**4.99**
39.	16.66	Decanal	2432573	0.08
40.	16.90	Acetic acid, octyl ester	1222717	0.04
41.	17.09	2-Propenal, 2-methyl-3-phenyl-	16209530	0.54
42.	17.22	1-Cyclohexene-1-carboxaldehyde, 2,6,6-trimethyl	2738856	0.09
43.	17.36	2,6-Octadien-1-ol, 3,7-dimethyl	2340510	0.07
44.	17.4	6-Octen-1-ol, 3,7-dimethyl-, propanoate	1357101	0.04
45.	17.5	Thujone	2617820	0.08
46.	17.70	Cyclohexanol	5714134	0.19
47.	17.93	Butanoic acid, 2-methyl-, hexyl ester	1607450	0.05
48.	18.03	2-Cyclohexen-1-one,2-methyl-5-(methylethenyl)	1196235	0.04
49.	18.29	1-Hexadecanol	20764441	0.69
50.	18.51	**Thymol**	315365379	**10.59**

51.	18.67	Cyclohexanone, 2-methyl-5-(1-methylethenyl)	2753953	0.09
52.	18.95	2-Cyclohexen-1-one,2-methyl-5-(1-methylethenyl)	5500474	0.18
53.	19.15	□-Myrcene	2103524	0.07
54.	19.52	Limonene	2034208	0.06
55.	19.88	Thymol	9394058	0.31
56.	20.02	Phenol, 2-methyl-5-(1-methylethyl)	5134259	0.17
57.	20.28	Acetophenone, 4'-methoxy	3447020	0.11
58.	21.41	Ethanone, 1-(3,5-dimethylpyrazinyl)	2406065	0.08
59.	21.68	Eugenol	8635746	0.29
60.	22.74	**Menthone**	523787508	**17.59**
61.	22.9	Propanoic acid, 2-methyl-, butyl ester	1633462	0.05
62.	23.99	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl	5226593	0.17
63.	24.22	Thujopsene	1678917	1.05
64.	24.61	Caryophyllene	116611193	3.91
65.	24.83	**□-Caryophyllene**	1981751	**6.06**
66.	26.5	□-Cubebene	60037377	2.01
67.	26.93	Azulene	28992883	0.96
68.	27.25	Diethyl Phthalate	2640266	0.08
69.	27.42	Copaene	1024593	0.03
70.	28.41	1,4-Methano-1H-indene,octahydro-4-methyl-8-methylene	3001824	0.10
71.	28.74	Fenchyl acetate	3007643	0.10
72.	29.23	Caryophyllene oxide	35712490	1.81
73.	29.69	1,4-Benzenediamine-diethyl	2663135	0.08
74.	30.09	3-Oxo-beta-ionone	2198500	0.07
75.	30.22	Menthol	1120296	1.03
76.	31.22	Globulol	3431510	0.11
77.	32.72	Propanal	700994	0.02
78.	33.0	1-Tridecene	1716386	0.05
79.	33.84	Acetic anhydride	10217319	0.34
80.	34.5	2-Dodecanone	848539	0.02

81.	36.38	Furfural	1720490	0.05
82.	36.48	Niacin	2318304	0.07
83.	36.92	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethy	1237924	0.04
84.	38.21	n-Hexadecanoic acid	5519953	2.18
85.	42.75	1-Dodecanol	1535103	0.05
86.	44.29	n-Decanoic acid	1062986	0.03
87.	51.79	Tridecane	1939154	0.06
			TOTAL	100.0

3.Result of the Discussion

In this study, the essential oil composition of *Mentha longifolia* subsp. *longifolia* was analysed by Gas Chromatography-Mass Spectrometry (GC-MS). As a result of the analysis, a total of 87 different components were identified; among these components, eucalyptol (28.89%), menthone (17.59%) and thymol (10.60%) were particularly prominent. These compounds are natural substances of pharmacological importance, which are frequently emphasised in the scientific literature with their antimicrobial and antioxidant effects (Baser & Buchbauer, 2010; Soković et al., 2010).

Eucalyptol (1,8-cineole) is known for its antimicrobial and anti-inflammatory properties, which make it valuable in various medical applications ((Baser & Buchbauer, 2010; El Omari et al., 2024). Menthone exhibits antimicrobial and antioxidant activities, making it useful in both food preservation and medical contexts (Ćavar Zeljković et al., 2021; Hudz et al., 2023). Thymol is especially recognized for its potent antimicrobial, antifungal, and antioxidant effects (Brasesco et al., 2017; Martinez-Pabon et al., 2020). The anti-inflammatory properties of eucalyptol, in particular, have been extensively documented in various studies (Baser & Buchbauer, 2010). The antimicrobial properties of menthone indicate its potential use in both food preservation and cosmetic products (Hudz et al., 2023; Cavar Zeljković et al., 2021). Thymol has been highlighted as a significant microbial control agent, especially in food safety and oral health. Additionally, studies have shown that thymol and eucalyptol can exhibit synergistic effects when used together (Brasesco et al., 2017).

The findings obtained support the potential applications of this species both in the food sector (as natural preservative and flavouring) and in cosmetics and pharmaceuticals. In particular, menthol is used in chewing gum, confectionery and beverage industry due to its stomach relaxing effects and terpene-rich structure. Due to its antioxidant content, it is effective in neutralising free radicals and is also preferred in anti-aging cosmetic products (Viuda-Martos et al., 2008). This study aims to provide a scientific basis for the potential industrial and pharmacological use of *Mentha longifolia* subsp. *longifolia* by revealing its chemical profile in detail.

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PNEUMATIC PROPORTIONAL VALVE CONTROL WITH FUZZY LOGIC

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ABSTRACT

Pneumatic systems are widely used among automation components in the industry. They contribute to the increase in efficiency and quality in mass production. Being safe, clean and straightforward in structure increases the possibility of preference. In addition, features such as friction effect and compressibility of air (nonlinear) are dynamics that require attention at the control point. Control of designs carried out in this direction is of particular importance. Uncertain evaluations such as less, more, cold, and hot are challenging situations encountered in daily life. Uncertainties encountered in industry are also weak points of control systems. Today, effective control can be achieved against uncertainties with Fuzzy Logic modelling. The system can be realized with fuzzy logic applications to exhibit high stability and low energy and time consumption. In this study, the control of a proportional valve in a pneumatic system is provided with fuzzy logic and a sensitive actuator efficiency is obtained. The reference voltage applied to control the proportional valve is calculated without any loss of time thanks to the input and output membership functions and the rule base. In the study, the current position of the cylinder and the position information that should be for the next job were processed, and the output value was converted to the reference voltage so that the proportional valve could make the necessary direction. In the design, it was planned that the system would be more economical than alternative control methods with this setup using the Arduino code editor and card. The design created from the study will be the preferred setup with the sensitive control results obtained in the system, including nonlinear (friction, fluid compression, etc.) dynamics. A pioneering record was created for more efficient and economical results to be obtained in the future with developing technology.

Keywords: Fuzzy Logic, Pneumatic Proportional Valve, Precision Control.

BULANIK MANTIK İLE PNÖMATİK ORANSAL VALF KONTROLÜ

ÖZET

Pnömatik sistemler, endüstride otomasyon bileşenleri arasında yaygın olarak kullanılmaktadır. Seri üretimde verim ve kalite arttışına katkı sağlamaktadır. Güvenli, temiz ve basit yapılı olmaları tercih olasılığını arttırmaktadır. Bunun yanında sürtünme etkisi, havanın sıkıştırılabilirliği (nonlineer) gibi özellikler ise kontrol noktasında dikkat gerektiren dinamiklerdir. Bu doğrultuda gerçekleştirilen tasarımların kontrolü ayrı önem teşkil etmektedir. Kesin olmayan az, çok, soğuk, sıcak olarak yapılan değerlendirmeler günlük hayatta da karşılaşılan zorlayıcı durumlardır. Endüstride karşılaşılan belirsizlikler de kontrol sistemlerin zayıf noktalarıdır. Günümüzde belirsizliklere karşı Bulanık Mantık modellemeleri ile etkili kontrol sağlanabilmektedir. Sistemin düşük enerji ve zaman tüketiminin yanında yüksek kararlılık sergilemesi bulanık mantık uygulamaları ile gerçekleştirilebilmektedir. Bu çalışmada bir pnömatik sistemde oransal valfin kontrolü bulanık mantık ile sağlanıp hassas bir aktüatör verimi elde edilmiştir. Oransal valfin kontrolü için uygulanan referans gerilimi girdi ve çıktı üyelik fonksiyonları ile kural tabanı sayesinde zaman kaybı olmadan hesaplanmıştır. Çalışmada, silindirin mevcut konumu ve sıradaki iş için olması gereken konum bilgileri işlenmiş, çıktı değeri oransal valfin gerekli yönlendirmeyi yapabileceği referans gerilimine dönüştürülmüştür. Tasarımda Arduino kod editörü ve kartı kullanılarak sistemin bu kurgu ile alternatif kontrol yöntemlerine göre daha ekonomik olması planlanmıştır. Çalışma sonucunda oluşturulan tasarım, doğrusal olmayan(sürtünme, akışkan sıkıştırılması gibi) dinamikler barındıran sistemde elde edilen hassas kontrol sonuçları ile tercih edilen kurgu olacaktır. Gelişen teknoloji ile ilerleyen zamanda alınacak daha verimli ve ekonomik sonuçlar için öncü kayıt oluşturulmuştur.

Anahtar Kelimeler: Bulanık Mantık, Pnömatik Oransal Valf, Hassas Kontrol.

Introduction

The fact that pneumatic systems are clean, safe and frequently preferred in the industry has triggered studies on sensitive control. The nonlinear dynamics contained in pneumatic systems necessitate these studies. In this study, a control system based on Fuzzy Logic was created. In different studies, methods such as artificial neural networks, PID (Proportional Integral Derivative) control methods and hybrid controls can be preferred. Proportional-integral-derivative (PID) control is a control method with an important place and importance in solving control problems related to industrial processes. PID control is expressed depending on the proportional value of the error signal (P), its integral concerning time (I) and its derivative for time (D). The controlled signal is taken and compared with the reference signal. The PID controller evaluates the difference between the input and output signal and the proportional signal, and the most suitable output signal is produced for the system to eliminate the error and be applied to the system. For the system to operate as desired, PID parameters must be adjusted. In addition to various methods, such as manual adjustment and calculation of parameters, there are also automatic adjustment methods (Birok, 2013). Pandian et al. investigated the usability of the pneumatic motor instead of the electric motor in their study. The mathematical model of the pneumatic motor was derived to make a performance comparison (Pandian, et al. 1999). Among the intelligent control methods, systems can be identified with artificial neural networks. In the study conducted by Özçalık and Küçüktüfekçi, forward and reverse identification of a direct current motor was carried out with a multi-layer artificial neural network (Özçalık and Küçüktüfekçi, 2003). In the study conducted by Shi and Sepehri, the control of the movement of a pneumatic piston was carried out with an adaptive artificial neural network-based fuzzy controller (Shi and Sepehri, 2004). In 2004, Akyıldız, in his master's thesis, sent a white noise signal to the system for system diagnosis purposes, recorded the system's position and pressure responses, then processed this data numerically and created a parametric model of the system. To eliminate the steady-state error observed in the previous PID control study of the system, a Model Predictive Control - Dynamic Matrix Control strategy was applied. To run this in real-time, a program was written in the Matlab-Simulink environment, and the code he obtained using Matlab Real-Time Workshop was used to monitor the system's real-time position (Akyıldız, 2004). Cajetinac et al. tried to develop a cheaper pneumatic servo system by using open/close electromagnetic valves (2/2 or 3/2) instead of proportional and servo valves. The pneumatic actuator was controlled by open/close type electromagnetic valves and pulse width modulation technique (Cajetinac, et al. 2012). Gyeviki et al. implemented a sliding regime control application using a 5/3 proportional pneumatic valve and PLC (Programmable Logic Controller) and achieved position control within ±0.02 mm. They showed in their experimental studies that the implemented sliding regime controller gave a fast response time and good transient performance (Gyeviki et al. 2011). Yilmaz determined that his study aimed to investigate the performance of a servo pneumatic system containing a linear cylinder and proportional valve with a PID controller to improve its low-speed characteristics (Yilmaz, 2008). Altun et al., who provided speed control of the stepper motor, which is frequently used in industrial applications with fuzzy logic, achieved successful results. Due to its cost and ease of use, Arduino was preferred over PLC, a control unit widely used in the industry (Altun, et al. 2016). In his master's thesis, Anlak preferred a fuzzy logic-based approach to solve uncertainties such as unwanted vibrations at the system output and improve system performance in the operation of hydraulic test machines, where PID control is widely used in practical applications. As a result of his studies, he found a 10% improvement in system performance (Anlak, 2021). In this study, the purpose of choosing fuzzy logic control is to give the optimum response in economic conditions against the possibilities that may be encountered

in the system. In the study, the sensitivity and importance of creating a fuzzy logic rule base come to the fore. In line with these rules, the system automatically produced the most appropriate solution for the situation and responded positively to the expectations of precision and speed. The created system aimed to provide an economic advantage over alternatives such as PLC, which is used in the industry by using Arduino among microcontrollers (Altun et al. 2016).

Materials and Methods

Pneumatic proportional directional control valves (5/3) are directional control valves supplied with 24V DC operating voltage and controlled with reference voltages in the range of 0-5-10V DC. In the study, the proportional valve used with the 5V reference was positioned in the middle position, and the fluid movement was stopped (Figure 1). Flow control was performed in the left and right positions of the proportional valve with the reference value between 0-5V and 5-10V. In intermediate values (such as 3.7 - 6.2), there are also differences in our flow rate, resulting in control differences (FESTO, 2024).



Figure 1. Pneumatic proportional directional control valve

In the face of such variable situations and possibilities, the control system's effectiveness can be increased with fuzzy logic applications. The actuator needed for the job can be integrated into the systems. The study realised a standard cylinder drive with the controlled directional control valve (Figure 2).



Figure 2. Standard cylinder

To examine the effectiveness of the control system and the results in detail, cylinder position sensors were used to create different position points on the cylinder (Figure 3). The opportunity

to control the effectiveness of the design was created with scenarios on movements in different directions and distances.



Figure 3. Cylinder sensor

The current position of the cylinder and the position information that needs to be found for the next task were transmitted as fuzzy values to the rule base from our membership functions as input information of our fuzzy logic model. The rule base clarified this value, and the output signal was created (Figure 4 and Figure 5).

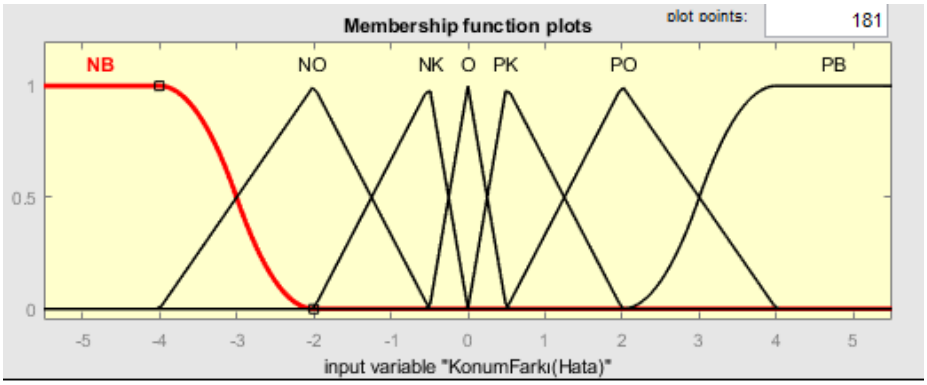


Figure 4. Membership function

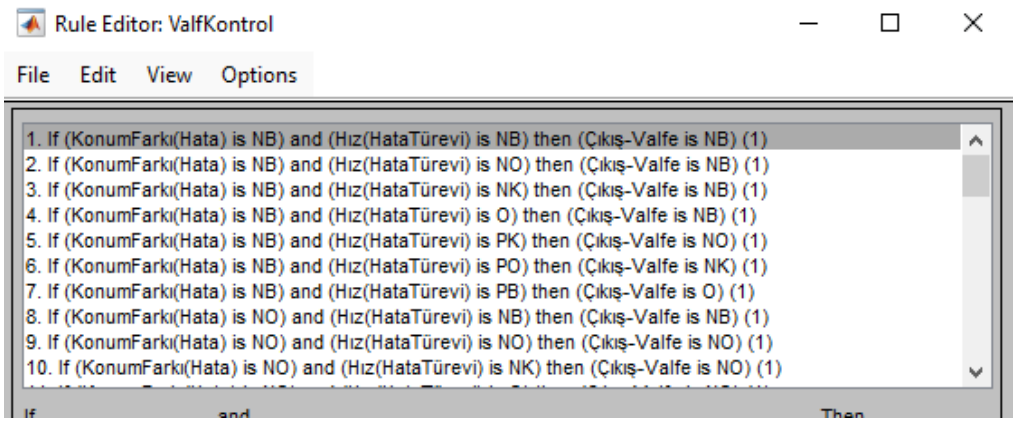


Figure 5. Examples of rules

The integrity of the design was achieved with the Arduino card and editor, which are microcontroller-based circuit boards (Figure 6).



Figure 6. Microcontroller-based circuit board

Findings and Discussion

The reference voltage was transmitted to the proportional directional control valve in the study with the clarified output signals given. The valve provided efficiency and the desired action from the cylinder by directing the fluid according to the reference voltage in line with the operating principle (Figure 7). The function for the output value determined the range of 0-10. The aim is to facilitate the adaptation of the proportional directional control valve to the operating structure at 0-5V and 5-10V reference voltages.

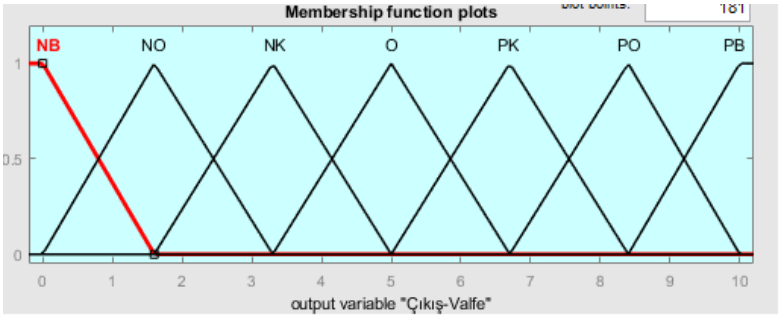


Figure 7. Output function

In input memberships, (-) values indicate that the cylinder moves in the opposite direction of the specified. If the proportional direction control valve is positioned to the right with a reference voltage of 5-10V and moves the cylinder in the right direction, then with a reference voltage between 0-5V and a (-) position difference input, it is positioned to the left and ensures that the cylinder moves in the left direction. In Figure 8, the surface map and the values are seen together.

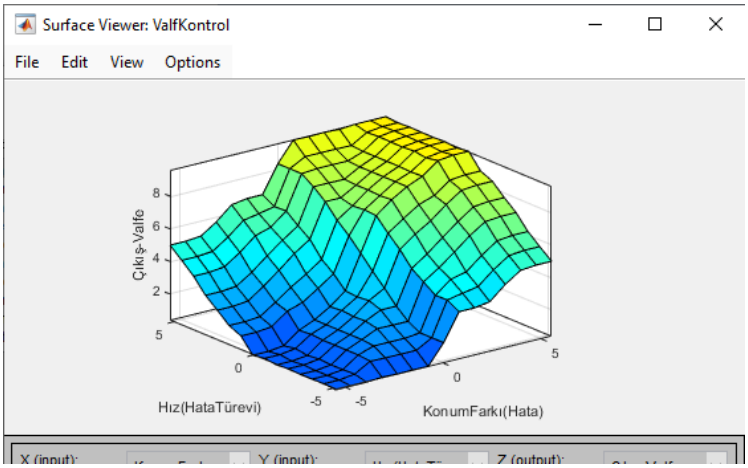


Figure 8. Surface map

The values of the output signals as a result of different input values are seen in the rule diagrams in Figure 9, Figure 10 and Figure 11. The output signal is compatible with the reference voltage required for the proportional directional control valve to direct the fluid as desired.

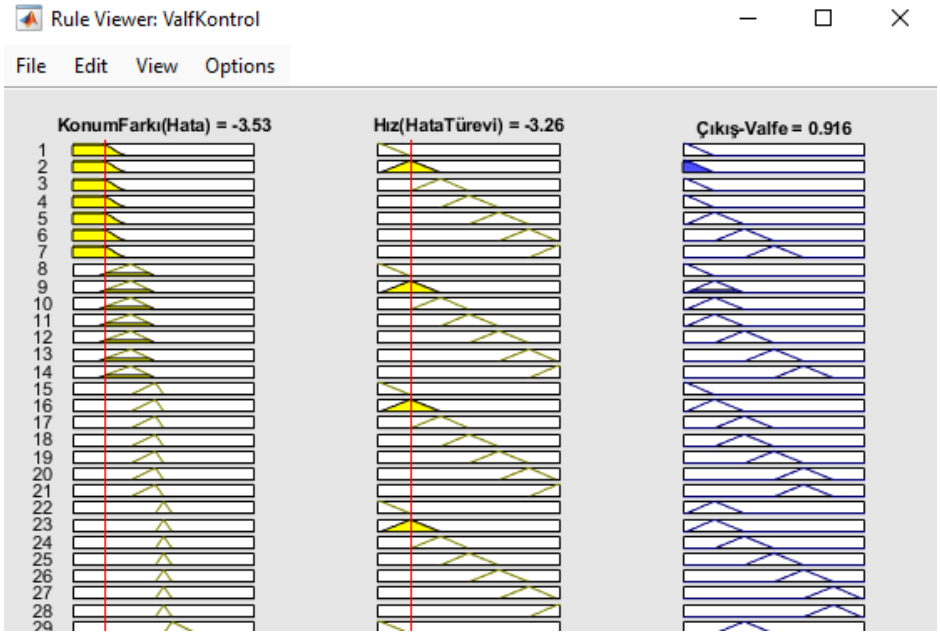


Figure 9. Rule diagram-1

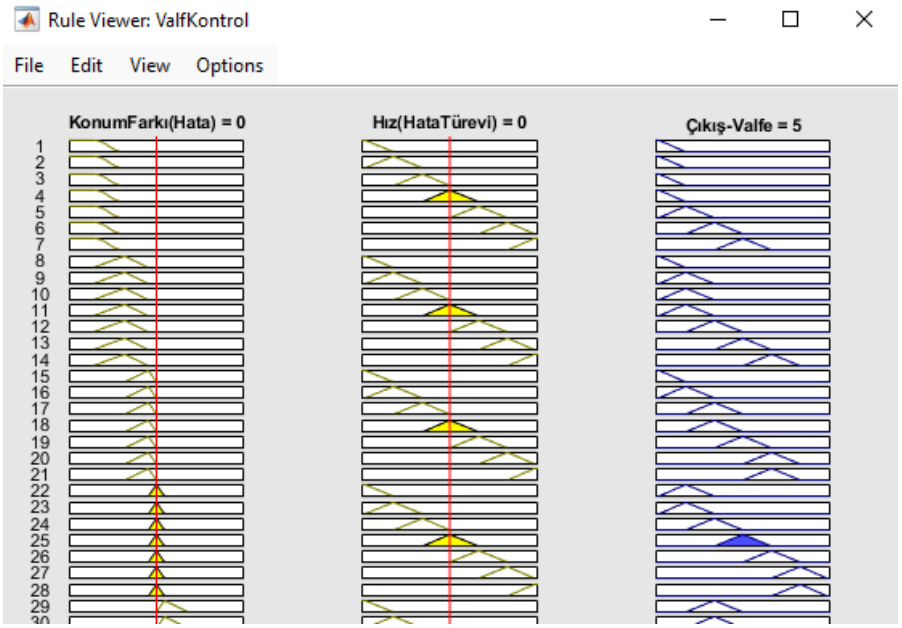


Figure 10. Rule diagram-2

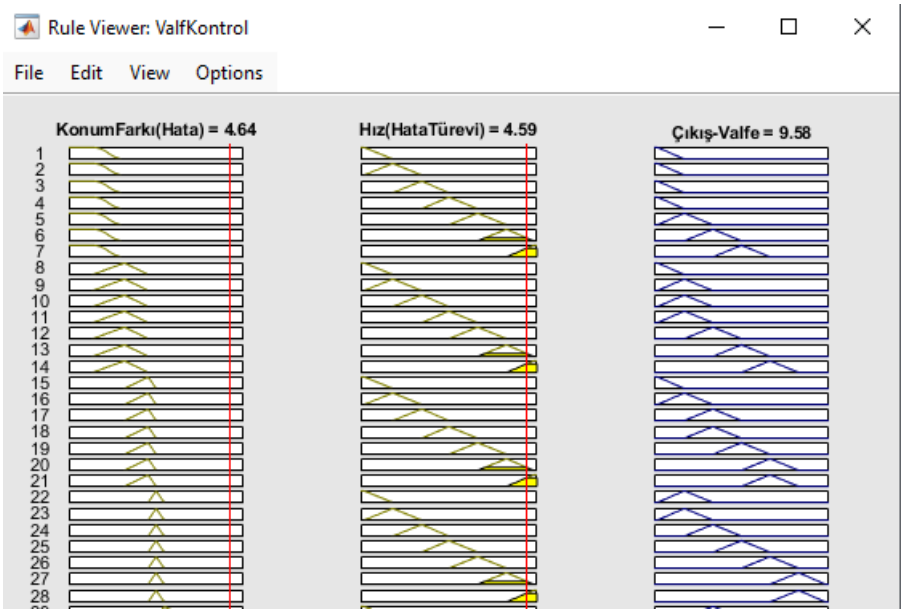


Figure 11. Rule diagram-3

Conclusion and Recommendations

The competition in the industry is getting fiercer with the development of technology day by day. As a result of changing needs and production, energy consumption and costs are increasing. In this direction, energy-saving, clean, low-cost, automatic controlled systems provide advantages. For these reasons, pneumatic systems are preferred components in automation. For this reason, there are many studies on the increase in control and efficiency. The difficulty of controlling the fluid in the system, the lack of automation, and efficiency loss are the parameters that must be prevented. In this study, a pneumatic proportional directional control valve, one of the latest technology products, was controlled with a fuzzy logic-based controller. This study developed a system that responds to scenarios other than the difficulty of controlling the fluid, system uncertainties and open-close clarity. In addition, this study

increased the automation efficiency. The variable control activity of the valve with intermediate reference values contributed to speed and energy saving. The cushioning feature inherent in the first and last positions of the cylinder was also provided in intermediate positions with the changing reference voltage of the valve. Therefore, the valuable life loss and maintenance costs were reduced with the vibration and impact effect of the cylinder. Thus, an alternative method was created for sensitive control studies in pneumatic systems.

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FINE-TUNING A BERT-BASED MODEL FOR AUTOMATED CLASSIFICATION OF CVE RECORDS USING CVSS METRICS

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ABSTRACT

The increasing integration of digital technologies across various sectors has led to a corresponding surge in cybersecurity threats, making the accurate and efficient analysis of vulnerabilities a critical requirement. The Common Vulnerabilities and Exposures (CVE) system serves as a standardized global framework for cataloguing security vulnerabilities by assigning unique identifiers to each issue. Complementing this, the Common Vulnerability Scoring System (CVSS) offers a consistent methodology for quantifying the severity of vulnerabilities through a set of well-defined base metrics. This study presents a deep learning-based approach for the automatic classification of CVE records using CVSS vector components, leveraging the capabilities of the Bidirectional Encoder Representations from Transformers (BERT) model. The dataset comprises up-to-date CVE entries sourced from the cvelistV5 repository maintained by the CVE Program on GitHub. The pre-trained bert-base-uncased model available on the Hugging Face platform was selected as the foundation and subsequently fine-tuned using 10,000 training samples and 2,000 testing samples. Classification was performed across eight CVSS base metric categories: Attack Vector (AV), Attack Complexity (AC), Privileges Required (PR), User Interaction (UI), Scope (S), Confidentiality (C), Integrity (I), and Availability (A). These metrics span between two to four discrete class labels each. The model achieved classification accuracies of 89.89% (AV), 90.70% (AC), 75.42% (PR), 90.82% (UI), 89.08% (S), 80.95% (C), 81.90% (I), and 81.11% (A), respectively. The results indicate that transformer-based language models can significantly enhance the automation and accuracy of vulnerability classification tasks, contributing to improved threat management in cybersecurity domains.

Keywords: Deep Learning, Cybersecurity, CVE Classification, CVSS Metrics, Vulnerability Assessment.

Introduction

With the rapid advancement of technology, digitalization has emerged as a central focus for organizations and institutions. Many companies have transitioned from manual operations to digital environments, streamlining their processes and increasing efficiency. Consequently, cybersecurity has become a critical concern. One essential aspect of cybersecurity is the determination of vulnerability scores, which play a pivotal role in assessing the protection level of an organization's digital assets and in implementing proactive measures against potential threats. Vulnerability scores quantify the severity of system vulnerabilities and the associated risk levels. This quantification facilitates the prioritization of security measures, allowing limited resources to be allocated efficiently toward addressing the most critical vulnerabilities. By doing so, organizations can mitigate the potential impact of cyberattacks and reduce associated losses. Furthermore, vulnerability scores serve as important reference points in various domains, including regulatory compliance, insurance evaluations, and third-party security audits. These scores help assess an organization's cyber resilience and inform strategic decision-making. Given their multifaceted utility, vulnerability scoring is widely recognized as a fundamental component of an effective cybersecurity strategy.

The concepts of Common Vulnerabilities and Exposures (CVE) and Common Vulnerability Scoring System (CVSS) are frequently used to calculate vulnerability scores in the field of cyber security. CVE is a standardized system for identifying and cataloging cybersecurity vulnerabilities, providing a unique identifier for each vulnerability to facilitate information sharing and coordination. CVSS is a framework that quantifies the severity of vulnerabilities using a numerical score from 0 to 10, based on metrics such as exploitability (e.g., attack vector, complexity) and impact (e.g., confidentiality, integrity, availability). The CVSS score is critical as it enables organizations to prioritize remediation efforts by assessing the potential risk a vulnerability poses. The score is calculated using a formula that combines base metrics (inherent vulnerability characteristics), temporal metrics (evolving factors like exploit availability), and environmental metrics (organization-specific contexts). Customized CVSS score estimation, tailored to an organization's specific environment, enhances risk assessment by accounting for unique system configurations and operational priorities. Estimating CVSS scores from vulnerability descriptions is beneficial, particularly in early-stage analysis, as it allows rapid prioritization before detailed assessments, though it may lack precision without full context. This integrated approach supports effective vulnerability management in academic and practical cybersecurity research.

In the CVSS framework, each base metric category is associated with a specific multiplier used in the calculation of the overall vulnerability score. Accordingly, the accurate classification of a given vulnerability within these predefined metric categories is critical to determining an accurate CVSS score. Various methods are employed to perform this classification, including expert analysis, adherence to standardized guidelines, and the use of automated tools (Khazaei et al., 2015; Sun et al., 2023). While expert-driven evaluations and standard guideline-based classifications often yield reliable results, these approaches become increasingly challenging as the volume of vulnerabilities grows. The scalability of manual methods is limited, and the likelihood of human error rises proportionally with the number of vulnerabilities. Consequently, there has been a growing demand for automated systems that can classify vulnerabilities efficiently and accurately. These systems offer a scalable solution to support consistent and timely CVSS scoring, particularly in environments where large volumes of vulnerability data must be processed.

A review of the literature reveals that various studies have been conducted on CVE classification based on CVSS metrics. In the study conducted by (Khazaei et al., 2015), a classification approach was developed for calculating CVSS scores using data obtained from the open-source vulnerability database. Feature extraction was performed using text mining techniques, and the performance of fuzzy systems, support vector machines, and random forest methods was compared. The results indicated that fuzzy systems outperformed the other two methods. In a study led by (Kühn et al., 2023), a deep learning-based model was proposed to predict the CVSS vector. By analyzing reference websites in the National Vulnerability Database, the study achieved better results compared to previous research. (Kekül et al., 2024) employed word embedding and multi-class classification methods to predict CVSS 2.0 and CVSS 3.1 metrics. Their analysis, based on data from the National Vulnerability Database, achieved an accuracy ranging from 87.34% to 96.25% for CVSS 2.0 and from 84% to 90% for CVSS 3.1. (Kekül et al., 2021) used natural language processing techniques in combination with naïve Bayes, decision tree, k-nearest neighbour, multi-Layer perceptron, and random forest classifiers to develop a standard-compliant prediction model on a general dataset. (Kai et al., 2023) applied data augmentation techniques and an optimal subset integration method in their study, utilizing the DistilBERT model for classification to calculate CVSS metric scores. The analysis results demonstrated that the proposed model operated more efficiently than manual evaluation and achieved higher accuracy compared to similar studies. In a study where a pre-trained XLNet-based model was fine-tuned on a specific dataset, the model achieved better performance in predicting CVSS metric scores compared to existing studies in the literature (Shi et al., 2022). (Nowak et al., 2021) proposed machine learning algorithms to facilitate the transition from CVSS 2.0 to CVSS 3.x by enabling the conversion of scores between the two versions.

Effectively managing security vulnerabilities is crucial for organizations, a fact consistently highlighted in research. As digitalization advances, the significance of robust vulnerability management is only expected to increase. A key aspect of this process involves prioritizing vulnerabilities by assigning them scores. This study introduces an innovative approach to this challenge by proposing and fine-tuning a language model designed to classify security vulnerabilities based on CVSS metrics. This offers a novel alternative within the field of security vulnerability management.

Materials and Methods

In our study, a dataset was created using the repository available on the official CVE website (*CVE: Common Vulnerabilities and Exposures*, 2025). The CVE List documents publicly known security vulnerabilities and defines them using standardized naming conventions. Each CVE entry includes a unique CVE ID, a brief description of the vulnerability, and links to additional information.

For CVSS classification, the eight primary metrics defined in CVSS version 3.1 were utilized (*CVSS v3.1 Base Score Calculator*, 2025). These metrics are as follows:

- Attack Vector (AV): Describes how the vulnerability can be exploited. It includes four categories: Network (remotely exploitable), Adjacent (limited by logical topology), Local (requires read/write/execute capabilities), and Physical (requires physical interaction).

- Attack Complexity (AC): Indicates the conditions required for a successful attack. It has two categories: Low (no special conditions) and High (specific conditions required).
- Privileges Required (PR): Specifies the level of privileges an attacker must possess. The categories are: None, Low (basic user privileges), and High (administrator privileges).
- User Interaction (UI): Indicates whether user interaction is necessary for the exploitation of the vulnerability. The categories are: None and Required.
- Scope (S): Describes whether the vulnerability impacts components beyond the security scope of the vulnerable component. It has two values: Unchanged and Changed.
- Confidentiality (C): Assesses the impact on data confidentiality. The categories are: High (complete loss), Low (partial loss), and None.
- Integrity (I): Assesses the impact on data integrity. The categories are: High (complete loss), Low (some changes), and None.
- Availability (A): Assesses the impact on the availability of the affected component. The categories are: High (complete loss), Low (performance degradation), and None.

For our classification task, we utilized BERT-base-uncased, a pre-trained language model readily available on the Hugging Face platform. BERT, or Bidirectional Encoder Representations from Transformers, is a powerful language representation model first introduced by (Devlin et al., 2019). It's built upon a bidirectional Transformer architecture, enabling it to process language context from both directions simultaneously. The "base" version of this model features 12 Transformer layers. Each layer incorporates 768-dimensional hidden vectors and employs 12 multi-attention heads, allowing for robust feature extraction. The "uncased" variant, which we used, preprocesses text data by converting it to lowercase and removing punctuation marks, simplifying the input. This specific model, comprising approximately 110 million parameters, was pre-trained on a massive corpus: the BooksCorpus dataset (800 million words) and the English Wikipedia dataset (2.5 billion words) (Wolf et al., 2020).

Findings and Discussion

In our study, a training dataset consisting of 10,000 samples was created from data obtained from the CVE website, and a test dataset was constructed using 2,000 samples. Following the dataset preparation, the BERT model was implemented using the torch and transformers libraries. Model training began with the pre-trained model described in the Materials and Methods section. During training, the batch size was set to 16, the number of epochs to 5, the learning rate to 2e-5, and the maximum sequence length to 256. The model was trained on the training dataset using these configured hyper-parameters, and its performance was evaluated on the test dataset. The resulting accuracy, precision, F1 score, and AUC score are summarized in Table 1.

Table 1. Performance scores of BERT model computing on test dataset

CVSS Metric Name	Number of Class	Accuracy (%)	Precision (%)	F1 Score (%)	AUC (%)
AV	4	89.89	88.70	88.81	93.88
AC	2	90.70	88.75	88.19	94.17
PR	3	75.42	75.43	74.81	88.59
UI	2	90.82	90.81	90.74	96.10
S	2	89.08	88.98	88.98	95.15
C	3	80.95	80.96	80.93	93.13
I	3	81.90	81.99	81.92	93.91
A	3	81.11	81.92	80.80	92.33

Table 1 presents the classification performance of the BERT model across various CVSS metrics. The results generally indicate a high level of performance for the model. Notably, the model achieved its strongest performance on the UI CVSS metric, demonstrating 90.82% accuracy and a 96.10% AUC score. Similarly impressive results were observed for the AV and AC metrics, with accuracy values exceeding 89% and AUC scores around 94%. However, for the PR, C, I, and A CVSS metrics, which each have three classes, accuracy values ranged between 75% and 82%. The relatively lower accuracy rate of 75.42% for the PR metric is particularly noteworthy. While these results suggest the model faces greater challenges distinguishing between certain metrics, the overall performance confirms that the BERT model offers effective and consistent performance in the automatic classification of CVSS metrics.

Conclusion and Recommendations

In this study, we developed and implemented a BERT-based deep learning model for the automatic classification of CVE records based on their CVSS base metrics. The model was trained and tested using current CVE data from the cvelistV5 dataset. Our classification results for the eight different CVSS base metrics demonstrate successful performance. We observed particularly high accuracy rates in the UI (90.82%), AV (89.89%), and AC (90.70%) metrics. However, the PR metric showed a lower accuracy rate of 75.42%, indicating that classification for this specific metric presents more challenges and offers an area for future improvement. This study makes significant contributions to both academic research and industrial applications. Automating CVSS scoring can lead to faster and more accurate analysis of cybersecurity threats, which in turn accelerates decision-making processes for security teams and optimizes resource allocation. Given the difficulties associated with manually classifying large-scale security vulnerabilities, our proposed method offers an effective and feasible alternative for automating this process.

The lower scores observed in some CVSS metrics suggest several avenues for future improvements. We anticipate that incorporating techniques like data augmentation and weighted loss functions could help mitigate class imbalances, leading to better performance.

Additionally, future studies could benefit from conducting analyses with other powerful language models such as XLNet, RoBERTa, and DeBERTa, and comparing their performance with our BERT-based model. This comparative analysis would enhance the originality of subsequent research. Finally, a promising direction for future work involves developing software or an API that integrates our model to analyze real-time CVE data. Measuring the impact of the trained model on real-time systems would offer a unique and valuable perspective for future studies in this domain.

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A STUDY ON THE CHARACTERISTICS OF PREGNANT WOMEN CONCERNING STUNTING AT THE MIDWIFERY CLINIC IN THE BAHKAPUL HEALTH CENTER WORKING AREA

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ABSTRACT

Stunting is a condition in which the height of an infant or toddler is shorter than that of other children of the same age. This condition is usually identified by the failure of growth in infants (0–11 months) and toddlers (12–59 months), which results from chronic malnutrition during the First 1,000 Days of Life. Stunting in children is a serious issue because it is associated with an increased risk of illness and death, impaired brain development, delays in motor skill development, and hindered mental growth. In North Sumatra, the stunting rate in 2021 was 25.8%, while in Pematangsiantar City, it was 15% which is below the national average of 24.4%. This study aims to describe the characteristics of pregnant mothers about stunting in the Batu Anam Health Center area, Simalungun Regency. The design of this research was descriptive with a cross-sectional design. The analysis uses univariate analysis to describe the characteristics of pregnant mothers. The population is pregnant mothers in the working area of Batu Anam Health Center from May 2024 to September 2024. The sample for this study was the whole population of 30 pregnant mothers. The results of the study showed that the majority of pregnant mothers who were aged 20-35 years (80%), the majority of pregnant mothers who had higher education (80%), the majority of pregnant mothers who were primigravida (50%), the majority of postpartum mothers who experienced tearing worked as housewives (60%), %), and the majority of pregnant mothers who have good knowledge about stunting (73.3%). The conclusion of the research above showed that most of the respondents of pregnant mothers who have good knowledge about stunting (73.3%).

Keywords : *pregnant mothers, stunting*

Introduction

Stunting is a nutritional problem caused by inadequate nutrition, leading to further nutritional issues. Ideally, adequate nutrition should begin from the time a child is in the womb until they reach the age of two years (the first 1,000 days of life). According to the Ministry of Health (Kemenkes), stunting is defined as a condition in which a toddler's z-score is less than -2.00 standard deviations (stunted) and less than -3.00 SD (severely stunted) (Kemenkes RI, 2022a). Stunting can be caused by both direct and indirect factors. The factors that can influence the occurrence of stunting include nutritional intake, exclusive breastfeeding, genetic factors, maternal education, maternal knowledge, infectious diseases, socioeconomic status, environment, and food availability.(Kemenkes RI, 2022a)

Stunting remains one of the major nutritional problems among toddlers in Indonesia. According to data from the World Health Organization (WHO) in 2020, 5.7% of toddlers globally were overweight, 6.7% were undernourished or severely malnourished, and 22.2% or 149.2 million children suffered from stunting (chronic malnutrition)(Kemenkes RI, 2022b). The stunting prevalence rate in Indonesia, based on the 2022 Indonesian Nutrition Status Survey (SSGI), was 21.6%, showing a decrease from the previous year's rate of 24.4%. Although the trend is decreasing, it is still considered high based on WHO criteria (>20%). The stunting prevalence in Pematangsiantar City according to SSGI (2022) was 14.3%.

Stunting has both short and long - term effects on a child's health. Short-term effects include impaired growth and development, and metabolic disturbances. Common characteristics of stunted children include short stature, delayed growth, learning concentration difficulties, and increased susceptibility to illness. If not addressed early, stunting can have long-term impacts such as reduced cognitive ability, greater vulnerability to diseases, and increased risk of metabolic disorders and conditions such as heart disease. Stunting can be prevented, starting as early as pregnancy. Pregnant women need to pay close attention to their nutritional intake during pregnancy. A mother's knowledge plays a crucial role in shaping her behavior regarding nutrition during and after pregnancy.(Kemenkes RI, 2022a)

A study conducted by Munthe (2022) found a significant relationship between the level of maternal knowledge and the incidence of stunting in children, with a p-value of 0.022, indicating that a low level of parental knowledge is associated with a higher incidence of stunting. The study also found a correlation between maternal knowledge and stunting prevention efforts.(Munthe, Atika, & Candra, 2023) Based on this background, the author is interested in conducting research titled: "The Characteristics Of Pregnant Women Concerning Stunting At The Midwifery Clinic In The Bahkapul Health Center Working Area.

Materials and Methods

This research method is descriptive and uses a cross-sectional design. The analysis used univariate analysis to describe the characteristics of pregnant mothers in the Batu Anam Health Center area, Simalungun Regency. The population of this study was population is pregnant mothers in the working area of Batu Anam Health Center from May to September 2024. The sample for this study was the whole population of 30 pregnant mothers, with as many as 30 respondents. The analysis uses univaraite to describe age, level of education, parity, employment status and knowledge about stunting of pregnant mothers at the Batu Anam Health Center in Simalungun Regency.

Findings and Discussion

This research is about the characteristics of pregnant mothers about knowledge stunting in the Batu Anam Health Center area, Simalungun Regency in 2024**.** This research was conduct in from May to September 2024. During this period, 30 respondents were obtained as a research sample. The results of the study obtained the following data :

Table 1. Characteristic of Respondents were by Age, Level Education, Parity Employment Status and Knowledge about Stunting Of Postpartum Mothers At The Batu Anam Health Center In Simalungun Regency.

No	Characteristic of Respondents	n	%
1	**Age**		
	- Risk Age (< 20 Years & > 35 Years Old)	6	20%
	- Not Risk Age (20-35 Years Old)	24	80%
	Total	**30**	**100%**
2	**Level of Education**		
	- Higher Education (SMA/PT)	24	80%
	- Low Education (SMP/SD)	6	20%
	Total	**30**	**100%**
3	**Parity**		
	- Primipara (1)	15	50%
	- Multipara (>1)	15	50%
	Total	**30**	**100%**
4	**Employment Status**		
	- Housewives	18	60%
	- Working	12	40%
	Total	**30**	**100%**
5	**Knowledge about stunting**		
	- Less Knowledge (<70)	21	70%
	- Good Knowledge (≥70)	7	30%
	Total	**30**	**100%**

-

- Base on the table above showed that that most of the respondents were not at risk age (were 20 to 30 years old), as many as 24 respondents or (80%), and very few of the respondents were at risk age (less than 20 years & more than 35 years old), as many as 6 or (20%) respondents. The majority of respondents, 24 respondents or (80%) had higher school education and very few of the respondents, 6 respondents or 20 % had low education. Half of the

respondents, 15 respondents (50%) had primipara parity, and half of the respondents, 15 respondents or 50 % had Multipara parity. Most of the respondents of pregnant mothers worked as housewives as many as 18 respondents or (60%) and almost half of the respondents, 12 respondents or 40 % was working. Most of the respondents had good knowledge about stunting, namely as many as 21 respondents (70%) and and almost half of the respondents, 7 respondents or 30 % had less knowledge.

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Conclusion and Recommendations

The results showed that most of the respondents were within the non-risk reproductive age group (20 to 30 years old), accounting for 24 respondents (80%). Meanwhile, a very small portion of the respondents, 6 individuals (20%), were considered to be in the at-risk age group (under 20 years or over 35 years old). A study conducted by Hasrun (2024) found a significant relationship between maternal age and the incidence of stunting in toddlers, with a p-value of 0.015.(Hasrun, 2024) These findings suggest that maternal age can influence the occurrence of stunting in children. Mothers who are either too young or too old are more likely to have children affected by stunting (Kemenkes RI, 2022a). The ideal reproductive age for women to conceive is between 20 and 35 years (Purborini & Rumaropen, 2023). A similar study was conducted by Sani (2020), who found a significant association between maternal age at the time of pregnancy and stunting among children aged 24 to 59 months in the service area of the Citeras Public Health Center. The study reported that 49 respondents categorized as being of high-risk maternal age (< 20 years and > 35 years) had children who were classified as having short or severely short stature (Sani, Solehati, & Hendarwati, 2020).

The majority of the respondents (24 respondents or 80%) had a high school level education, while only a few (6 respondents or 20%) had a lower educational background. This is consistent with the findings of Hasrun (2024), who reported a significant relationship between the mother's education level and stunting in toddlers, with a p-value of 0.000. (Hasrun, 2024)Low maternal education can affect the mother’s ability to absorb information, which in turn influences her behavior in preparing nutritious food for her child (Kemenkes RI, 2022a).

Half of the respondents (15 respondents or 50%) were primiparous (first-time mothers), while the remaining half (15 respondents or 50%) were multiparous. These findings indicate that maternal parity may influence the incidence of stunting. Closely spaced pregnancies and births can increase the risk of stunting in children (Kemenkes RI, 2022a).

Most of the pregnant respondents were housewives (18 respondents or 60%), while nearly half (12 respondents or 40%) were employed. According to a study by Savita (2020), there is a significant relationship between maternal employment and stunting among children aged 6–59 months in South Bangka Regency, with a p-value of 0.000 (Savita & Amelia, 2020). Similarly, Rahmawati (2023) found a significant relationship between maternal occupation and stunting in the working area of Landono Health Center, also with a p-value of 0.000 (Rahmawati, Zakiah, & Mutmaina, 2023). Working mothers are expected to have better access to information and resources through their experiences in the workplace (Savita & Amelia, 2020).

- Most of the respondents had good knowledge about stunting, namely as many as 21 respondents (70%) and and almost half of the respondents, 7 respondents or 30 % had less knowledge. The results of this study are also consistent with the research conducted by Juniantari (2024), which states that there is a relationship between maternal knowledge and the

incidence of stunting in toddlers in the working area of Puskesmas Abang I. The assumption of the researcher, Juniantari, states that if a mother has good knowledge, then her behavior regarding stunting will also be good (Juniantari, Triana, Sukmandari, & Purwaningsih, 2024). Mothers who have sufficient knowledge about stunting can also be influenced by other external factors that can contribute to the occurrence of stunting in children (Juniantari, 2024). This study is also in line with the research conducted by Asnawi (2024), which states that maternal knowledge is statistically significantly related to the incidence of stunting in children under five years old (p=0.209) (Asnawi et al., 2024). Similar research by Hamdin (2023) also states that there is a relationship between maternal knowledge and the incidence of stunting in toddlers in the working area of Puskesmas Moyo Hilir, Sumbawa Regency, with a p-value of 0.006 (Hamdin, Hamid, & Nurhayati, 2023).

Stunting in children can be caused by several direct and indirect factors. These factors include: toddler nutritional intake, infections, maternal factors, genetic factors, exclusive breastfeeding, food availability, socioeconomics, education level, knowledge, maternal nutrition knowledge, and environmental factors. Mothers with insufficient knowledge about nutrition may find it difficult to prepare nutritious food for their children. Conversely, when a mother has good knowledge, it is expected that her behavior and actions will align with the knowledge she possesses, allowing her to prepare good nutrition for her child and thus prevent stunting (Kemenkes RI, 2022a).

Stunting can result in disturbances in a child's growth and development, leading to long-term effects on their overall development. Stunting can even be prevented by paying attention to nutritional content starting from pregnancy. The role of the mother is crucial in preventing stunting, as the mother is primarily responsible for preparing the nutritional intake for the family. Therefore, mothers need to be equipped with knowledge about nutrition and stunting (Kemenkes RI, 2022a).

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USE OF INSECTS AS ALTERNATIVE PROTEIN SOURCES IN POULTRY FEEDS: A REVIEW

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ABSTRACT

Despite the exponential growth witnessed in the poultry industry in Nigeria over a few decades, there still exits deficiency in meeting the nutritional demands of the populace. To bridge this gap sustainably, the exploration of alternative protein sources away from the conventional, high-cost feedstuff such as fishmeal and soybean meal is imperative. Insect meal has emerged as a promising solution, offering high nutritional value and ecological benefits. This review examines the nutritional composition of insect meal such as the black soldier fly, house fly, grasshopper, cricket, meal worn, earthworm meals into poultry diets as well as their effects on the growth performance of poultry species. It was observed that insect meals possess nutritional compositions that are comparable to soybean and fishmeal respectively and can improve the growth performance of birds, hence, providing a affordable alternatives for poultry feeds. Furthermore, it describes challenges and future prospects associated with scaling up insect production. Despite facing limitations, insect meal presents a viable and eco-friendly option to enhance poultry nutrition. With ongoing research, insect-based feeds hold the potential to revolutionize the poultry industry, thereby ensuring food security.

Keywords: Insect Meal; Poultry; Alternative Protein Source; Nutrient composition; Food Security

INTRODUCTION

Poultry have strong affinity for worms and insect larvae. This is the reason their innate instinct of digging in and scratching of ground. Birds prefer insect-based diets, probably because of their taste and nutritive value. Birds reared on free range rely on insects to meet their protein needs. This indicates that insects and worms have excellent potentials for use as a replacement for highly competitive fishmeal and soybean meal in poultry production. According to Agazzi *et al*., (2016) insect meals are considered a possible protein source for use in animal nutrition based on the nutritive values. Veldkamp *et al.,* (2012) reported that insect meals have an amino acid profile and essential amino acid indices similar to those of soybean meal.

Insect meal as an alternative protein ingredient gives rise to diverse views for animal feeding, with a question of how to combine sustainability and quality (Reis & Dias, 2020). An efficient inclusion of insect meal can close the cycle in a sustainable circular economy (Veldkamp *et al.,* 2012). There is a high demand and consequent rise in the prices of fish and soybean meal necessitating the development of research on protein sources from insects (FAO, 2013). The inclusion of insect pupae and larvae in poultry feed does not affect meat quality and the performance of growing animals (Zegeye, 2020). The use of insects in animal feed results in low-cost feed since the production of these insects require simple technology with organic waste as input. However, according to Gasco (2019), the presence of chitin in some insect species could lead to a decrease in nutrient digestibility, interfering with animal performance.

Insect meal is environmental-friendly ingredient. It contributes to decreasing environmental pollution as organic wastes are used in insect production (Sayed *et al*., 2019; Sacci *et al*., 2018; Sacci *et al*., 2020). Insect meals are considered as potential substitution candidates for soybean meal (SBM) and fish meal (FM) since they have been used as partial or total substituents without adverse effects on production performances or product quality (Kah *et al*., 2018; Marorno *et al*., 2015; Bovera *at al*., 2015).

This paper is one of the numerous efforts geared towards providing ample information an about the nutritional value of some insect meals, as well as their effects on growth performance of poultry. The safety concerns regarding insects rearing or feeding insect-based diets are also discussed.

Nutritive value of Insect meal

The black soldier fly (BSF) is a common and widespread fly of the family *Stratiomyidae*. BSF meal is a naturally nutritious, protein-packed, and calcium-rich source. The concentration of crude protein (CP) in BSF larvae meal varies from 35 to 61%, and the content of crude fat (*CF*) ranges from 7 to 42%. High concentrations of lauric and palmitic acids are also reported (Moula *et al*, 2018). Methionine, lysine, threonine, and valine contents were found to be between 0.08 and 0.90% (Brede *et al*., 2018; Mwaniki *et al.,* 2018; De Marco *et al*, 2015), 0.34 and 3.30% (Neumann *et al*., 2018), 0.22 and 2.26% (Brede *et al*., 2018; Mwaniki *et al.,* 2018), and 0.33 and 3.38% (Brede et al., 2018; Mwaniki *et al.*, 2018) respectively. The concentration of calcium ranges from 1.21% (Mwaniki *et al*., 20) to 4.39% (Chu *et al*., 2020), and that of phosphorous varies from 0.74% (Liu *et al*., 2021) to 0.95% (Mwaniki *et al.*, 2018). The nutritive value of BSF meal depends on the rearing substrate, the age of harvesting, and the technology of processing. The pressing and defatting treatments could decrease fat content, from 37% (original) to 27.36% (steamed), 17.05% (methanol extracted), 17.95% (normal pressing), or 13.05% with heated pressing (Astuti *et al*., 2018).

The housefly (HF) can be found in all countries and can be reared on animal manure and food waste. HF larvae meal contains considerable amounts of CP and *CF* ranging from 40 to 64%,

and from 2.5 to 28%, respectively. In HF larvae, the content of CP decreases with age, whereas the content of *CF* increases (Aniebo *et al*., 2008, Aniebo and Owen, 2010). Lysine and methionine are the most limiting amino acids in poultry nutrition. Both of these amino acids are available in high amounts in HF meal (Hall *et al*., 2018). Interestingly, the amino acid profile of HF meal resembles that of FM. Similarly to BSF meal, the processing method of the insect impacts the nutritive value of the meal (Aniebo and Owen, 2010).

Mealworms (MW) can be found worldwide where warm, dark, and damp places are available. MW meal is considered a good source of protein and fat, with a CP amount ranging from 27 to 54%, and *CF* content from 4 to 34%. Values of ash, crude fibers, and energy in MW larvae range from 3.0 to 4.5% (Hall *et al.*, 2018; Jozenfiak and Engberg, 2018), 5.0 to 8.8% (Hall *et al*., 2018; Jozenfiak and Engberg, 2018), and 1,378 to 4029.63 Kcal/Kg DM (De Marco *et al*., 2015), respectively. As compared to SBM, MW larvae had higher CP, *CF*, and ADF (Bovera *et al*., 2018). Methionine + cysteine, lysine, leucine, isoleucine, histidine, threonine, valine, and arginine contents are higher in SBM, whereas MWs had greater tryptophan content (Bovera *et al*., 2018). Moreover, MW larvae contain low amounts of Ca (434.59 mg/Kg) and high levels of K and P [9479.73 and 7060.70 mg/Kg, respectively (Bavzanaadii *et al*., 2011)]. Consequently, the Ca/P ratio is not suitable for poultry production, especially for hens, and Ca supplementation is recommended (5). In addition to these minerals Zn, Fe, and Cu are found in MW in considerable amounts [104.28, 66.87, and 13.27 mg/kg, respectively (Bavzanaadii *et al*., 2011)].

Crickets and grasshoppers are also valuable protein sources for poultry. The amount of CP ranges from 48 to 65% and *CF* is between 3 and 21%. Of course, these contents varied between African grasshoppers (*Acanthacris ruficornis*), Chinese grasshoppers (*Acrida cinerea*), wild edible grasshoppers (*Ruspolia nitidual*), short-horned grasshoppers (*Oxya hyla hyla*), and desert locusts (*Schistocerca gregaria*) (Amobi *et al*., 2020). The crude fiber content varies between 1.06 and 9.21% (Ojewole *et al*., 2005; Hassan *et al*., 2009). In addition to crickets, earthworms (EW) are a good source of protein, energy, and amino acids (Jankovic *et al*., 2020; Istiqomah *et al*., 2009; De Marco *et al*., 2015). The CP content of EW meal ranges from 41 to 66%, and *CF* is between 3.5 and 18%. Important contents of lysine and methionine were recorded in EWs (Finke, 2002). However, it is important to mention that these values depend on the freshness and dryness of the EWs.



Fig 1. Some insects used in poultry feed. (Belhadj *et al*., 2023)

Effects of Insect Meal on Growth Performance

Housefly larvae and pupae have been extensively investigated in broilers (Awoniniyi *et al*., 2003; Adeniji 2003; Adesina *et al*., 2011; Okah and Onwu jiariri, 2012 Teguia *et al*., 2002). The various results pointed to the fact that this protein source, either fresh or dried, can be used as an alternative to fish meal, soybean meal, and other protein ingredients. The studies observed no adverse effect on survival rate, daily feed intake, body weight gain, and feed conversion ratio. However, a more balanced diet can be achieved by combining housefly meals and conventional meals in the same diet for better growth performance (Awoniniyi *et al*., 2003; Adeniji 2003; Adesina *et al*., 2011; Okah and Onwu jiariri, 2012 Teguia *et al*., 2002). Furthermore, housefly meal can partially or totally replace FM in broiler diets. Inaoka *et al*. (1999) and Awoniyi *et al*. (2003) reported that housefly maggots and pupae may be included in the diet up to 7%. If the inclusion rate exceeds 10%, a decrease in feed intake and growth performance was observed. This seems to be related to the dark color of the produced feed, which is not attractive to chickens (Atteh and Ologbenla, 1993), and to the imbalanced AAs profile (Makkar *et al*., 2014). In this latter case, methionine supplementation might improve broiler growth performance. Nevertheless, Hwangbo *et al*. (2009) concluded that growth performance was enhanced when supplementing broiler feed with 10–15% housefly larvae. Similarly, Okah and Onwujiariri (2012) described that the experimental group of chickens fed 20 and 30% of housefly maggot meal recorded the best body weight, as compared with the control group. It seems that this discordance regarding the inclusion rate is related to the processing method of the insect, which influences the availability of nutrients.

Mealworm meal is another alternative protein source that has investigated extensively in poultry feed. Hall *et al*. (2018) who reported that mealworm, once incorporated in the broiler diets up to 10%, has no negative effects on body weight gain, feed intake, and feed conversion ratio. It was also observed that a consequent decrease in the inclusion rate of SBM from 31 to 20% after incorporating dried yellow mealworm up to 10%, had no significant differences in the performance results. According to Schiavone *et al*. (2014), the best body weight gain was obtained using 25% mealworm. Bovera *et al*, (2015), reported no significant effects on growth performance, carcass traits, and meat quality on broiler chickens when soybean meal was completely substituted with mealworm. In addition, the feed conversion ratio was significantly enhanced ($p < 0.05$) in the mealworm group. As compared to the control group (SBM group), broilers fed MW as a unique protein source had a more developed digestive system, a greater percentage of the spleen, longer intestines, ileum, and ceca ($p < 0.05$). Indeed, a better feed conversion ratio was calculated in the experimental group (Bovera *et al*., 2015).

BSF is another potent candidate to be included in poultry feed as SBM and FM substitute. The nutritional profile of these worms is comparable to that of FM and, in some aspects, better than that of SBM. Maggot meal could replace FM, without altering body weight gain, feed intake, and feed conversion ratio. As a substitute for SBM, dried BSF larvae allowed for decreasing feed intake and enhancing feed conversion ratio, without adverse effects on body weight gain (Makkar *et al*., 2014). In growing broiler quails, no significant statistical differences were reported regarding body weight gain, feed intake, and feed conversion ratio, and mortality rate between control, 10% defatted BSF larvae meal, and 15% defatted BSF larvae meal groups (Cullere *et al*., 2016). Regarding palatability, no special preference for broilers was shown toward control or defatted BSF larvae meals. It is interesting to mention that in this latter study, 10% defatted BSF larvae substituted for 28.4% of soybean oil and 16.1% of SBM, and 15% of defatted BSF larvae meal allowed the replacement of 100% of soybean oil and 24.8% of SBM.

It can be concluded that BSF meal is a good alternative to FM and SBM in broiler diets, without any negative impacts on the growth performances of the birds.

Grasshoppers were also assessed in broilers' feed. Grasshopper meal was used to replace 50 and 100% of FM (the inclusion rate was 5 and 10%, respectively) in Arbor Acres broiler chickens, which exhibited improved growth (Brah *et al*., 2017). These findings were corroborated by the findings of Sanusi *et al*. (2013) and Sun *et al*. (2013) who reported that grasshopper meal could totally replace FM without any adverse effects in Anak 2000 broiler chickens. However, diets containing more than 25% wild edible grasshopper (*Ruspolia nitidual*) meal were found to lower FI in indigenous chickens (Nginya *et al*., 2019).

Earthworms were also recommended as a potential protein source that could replace FM and SBM in poultry feeding. Loh *et al*. (2009) reported that incorporating EWM in Ross male broiler chickens diets at 5, 10, 15 and 20% allowed enhancing feed intake ($p < 0.05$), increasing BW ($p < 0.05$), improving FCR ($p < 0.05$) and reducing fecal lactic acid bacteria count. Other related studies confirmed that Ross 308 broiler chickens fed on diets containing 2, 3%, or 4% EWM increased their BW and feed intake (Loh *et al*., 2009; Zang *et al*., 2018). An inclusion rate of 5% EWM (*Eudrilus eugeniae*) enhanced feed conversion ratio (Park and Hahm, 2005). Lower inclusion rates (1% EWM and 1% *vermi-humus*) resulted in a negative impact on body weight gain, despite the observed improvements in the immune functions in broilers (Zang *et al*., 2018). This was probably due to the unbalanced amino acid profile of the diet.

Challenges

Insect species, feed substrate, and processing methods play crucial roles in determining the nutritional quality of insect meal. Therefore, optimizing rearing conditions and processing techniques is essential to ensure that insect-derived feed products meet the nutritional requirements of poultry.**Limitations**

There are fewer number of cultured insect species and the dry matter content of insects constitutes a significant set-back. Also the production technology seem to vary from region to region and may resulting to inconsistent outputs. Another challenge lies in the presence of specific anti-nutritional compounds such as protease inhibitors, oxalates, tannins, lectins, and alkaloids in insect meal, which can affect nutrient absorption and animal health. Additionally, to gauge the economic feasibility of integrating insects into poultry feeding, regular cost-benefit analyses are necessary.

Prospects of insect meal

The future outlook for insect meal as an alternative protein source for poultry diets is promising. With continued research and development efforts, there is a greater possibility of fulfilling the growing demand for economical and sustainable protein sources in the poultry industry. By leveraging technological advancements, regulatory support, and ongoing research initiatives, insect-based feeds have the potential to play a significant role in addressing the protein needs of the poultry sector while contributing to sustainable agricultural practices.

Conclusion

In conclusion, the mass production of insects presents a promising opportunity to generate a sustainable novel feed ingredient for the poultry-feed sector while simultaneously addressing

the environmental impact of food waste. Applied research has demonstrated encouraging results, highlighting insect-derived products as one of the most intriguing and sustainable sources of nutrients for animal feed. However, it is important to acknowledge that the insect protein industry is still in its early stages of development. Further research is needed to fully explore the potential of insect-based feed ingredients, optimize production processes, and ensure product safety and quality. With continued innovation, collaboration, and regulatory support, the insect protein industry has the potential to make significant contributions to sustainable agriculture and food security.

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TOTAL FACTOR PRODUCTIVITY AND SUPPLY RESPONSE OF WHEAT PRODUCTION IN NIGERIA: AN EMPIRICAL ANALYSIS USING TÖRNQVIST-THEIL INDEX AND ARDL MODEL

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ABSTRACT

This study investigates the Total Factor Productivity (TFP) and supply response of wheat production in Nigeria over the period 1982 to 2022, utilizing secondary data obtained from the Food and Agriculture Organization (FAO), World Bank, and other climatic data repositories. The Törnqvist-Theil index was applied to estimate productivity, revealing a pattern of fluctuations across the decades. Average TFP values increased modestly from 0.96 in the 1980s to 1.04 in the 2012–2022 period. Notable peaks occurred in 1993 (TFP = 1.72) and 2007 (TFP = 1.49), while troughs were recorded in 1988 (TFP = 0.64) and 2020 (TFP = 0.65), indicating periods of inefficiency likely driven by infrastructural constraints and adverse climatic conditions. Additionally, the Auto Regressive Distributed Lag (ARDL) model was employed to assess short- and long-run supply responses. In the short run, wheat production was significantly influenced by lagged output (DPRQ(-2), $p = 0.0465$), wheat price ($p = 0.0054$), maize price ($p = 0.0141$), and humidity ($p = 0.0031$). However, none of the explanatory variables had statistically significant effects in the long run. The error correction term (-0.433, $p < 0.01$) confirms the presence of a stable long-run equilibrium, with approximately 43.3% of deviations corrected annually. These findings highlight the sensitivity of wheat production to both market conditions and environmental factors in the short-run, while emphasizing the need for sustained policy and technological interventions to improve long-run productivity.

Keywords: Total Factor Productivity (TFP), Wheat Production, Törnqvist-Theil Index, ARDL Model, Supply Response, Agricultural Productivity, Price Elasticity, Time Series Analysis.

1. INTRODUCTION

Agricultural production dropped, triggering food insecurity challenges in Nigeria (Ifeoma and Agwu, 2014). As noted by the Vision 20: 2020, National Technical Working Group (NTWG) on agriculture and food security, agriculture has always played a key role in the nation's economy, currently contributing about 42% of Gross Domestic Product (GDP) as against 13% for Oil & Gas; and employing two-thirds of the entire labor force, but, over the past 20 years, value-added per capita in agriculture has risen by less than one (1) percent annually (NTWG, 2009). The agricultural sector comprises crop production, fishery, livestock, and forestry, crop production is the dominant activity accounting for 87.6%, relative to livestock (8.1%), fishery (3.2%), and forestry (1.1%) In Nigeria (NBS, 2020). Nigeria's agricultural sector contributes to a significant part of the country's GDP. Between July and September 2021, agriculture contributed to almost 30 percent of the total GDP, an increase of about six percentage points compared to the previous quota in 2022 (Statista, 2023).

Wheat is grown in many different varieties throughout the world, each with unique uses and traits, the most common wheat type in Nigeria is bread wheat (Triticum aestivum), which is renowned for its high gluten content, making it ideal for baking, due to its tougher kernel and higher protein content than bread wheat, durum wheat (Triticum durum) is mostly used to make pasta, couscous, and some varieties of bread, Ancient wheat types like emmer wheat (Triticum dicoccum) have more nutritional content than contemporary wheat cultivars.

Wheat (Triticum Aestivum) is consumed in one way or another in almost all homes, restaurants, and lodging facilities across the nation. Furthermore, the crop serves as the primary raw material used in Nigerian flour mills. Its flour is used to make biscuits, bread, candy, and other treats. The offal (residue) is used in the feed mills in compounding livestock feeds (Ahmed, 2014). Due to the population's shifting tastes, there is an increasing local need for wheat products, which constantly generates a gap between local supply and demand, leading to a significant import of wheat into the nation. Wheat farming has been the most complicated area of Nigerian agriculture for the last decades, due to the high temperatures that is not favorable for the crop, low production, and many more (Haruna *et al.,* 2017).

Nigeria depends on imported wheat to meet the demands of its large growth. However, since the oil shock of the last quarter of 2014 up to 2016, wheat farming has attracted policymakers who see Nigeria's capacity in wheat production to be self-sufficient (KMPG, 2016). Throughout history, the Nigerian government's efforts to increase wheat production led to the ban on wheat importation in 1987, and the Accelerated Wheat Production Programme (AWPP) was implemented to encourage local production Nigeria's wheat production rose from 50,000MT to 450,000MT within three years of the program (Haruna *et al.,* 2017).

Nigerian wheat productivitys are no more than 2 tons per hectare, according to the Food and Agricultural Organization (FAO, 2020). This is significantly lower than irrigated wheat production in other countries, including Mexico at 5.1 tons per hectare, India at 3.4 tons, and Sudan at 2.5 tons. Low productivitys also lead to much higher prices in the local market than imports, making it difficult for millers to buy local wheat while keeping flour prices sustainable for Nigerian consumers. Unstable weather conditions and climate change create additional challenges, sometimes affecting wheat production planning and forecasting (Bamiro *et al.,* 2020). Other challenges include uncompetitive pricing, insufficient funding systems for research, lack of a cohesive national strategy on wheat development, unclear role of various stakeholders, and high cost of production (Danbazau *et al.*, 2021).

Solving Nigeria's cereal production problems is an indirect and powerful approach to alleviating poverty and improving the standard of living for Nigerian farmers. It is also a direct way of improving the GDP of the country. Mining policies and investment strategies must be designed and implemented at national levels to preserve soil nutrients, focusing on well-defined target areas. Furthermore, these measures must successfully promote the judicious use of inputs in conjunction with sound soil conservation practices (Ismaila *et al.,* 2010).

Abah and Ochoche (2021) state that during the past 20 years, wheat consumption has steadily increased throughout all African countries due to population growth, shifting dietary preferences, and a strong urbanization trend. This has resulted in a growing "food gap" in all regions, which is primarily filled by imports. Nigeria is becoming more and more enmeshed in the "wheat trap," where the majority of its food is produced using wheat (Ayo, 2010). The current domestic demand for wheat exceeds the amount produced locally. According to records, 90–95% of the wheat consumed comes from imports into the United States (Falaki & Mohammed, 2011). In conclusion, according to AgFlow report, (2023), Nigeria bought 0.14 million tons of wheat from Canada in July 2023, with Poland importing 64,365 tons, Russia importing 51,080 tons, and the United States importing 27,000 tons, hence Jan–to July 2023 saw 1.9 million tons of imports overall, Nigeria was buying 55,000 tons of wheat a year from Brazil, Latvia, Lithuania, and Poland.

Ochoche, (2021), study assessed the trend of wheat production in Nigeria and its implication on agricultural output (1981-2018), The production of wheat increased until 1987 throughout the specified period, after remaining constant from 1981 to 1984. However, a notable downturn started in 1987 and lasted until 1993. Production then climbed until 2000, fluctuating until 2006, when it increased dramatically and peaked in 2010. Up till 2018, output has continuously decreased after then. This described the complex nature of wheat production fluctuation in Nigeria, but how does the area harvested for wheat fluctuate? How does the productivity change over time? All these questions will be addressed in this study. Also, Determinants of Wheat Price Fluctuation in Nigeria (1981-2013) was accessed by,(Adefemi Oladejo *et al.,* 2019) the results show that wheat prices fluctuate over time, with an estimated intrinsic rate of price rise of 0.0238. Wheat prices were shown to be highly influenced by per capita income.

Thiam *et al.,* (2001) reveal that technical efficiency (TE) studies in agriculture show varying results across India, Pakistan, Ghana, and other African countries. In India, TE estimates range from 68% to 89% across crops like whole farm, wheat, and rice, with rice showing the highest efficiency. Pakistan's TE in rice production varies significantly from 24% to 73%, indicating a broader range of efficiency levels. Ghana exhibits moderate to high TE in rice production at 73%, similar to some of Pakistan's higher estimates.

Other African countries, such as Tanzania, are also considered to increase the geographical representation. These findings highlight diverse agricultural efficiencies and inefficiencies, providing valuable insights for comparing and improving yield efficiency in wheat cultivation in Nigeria by adopting best practices and avoiding common pitfalls observed in these regions.

A substantial research gap still exists in our understanding of the precise causes of productivity decline and the thorough examination of total factor productivity and supply response will help reveal some issues related to the input use, resources allocation and production responses toward various factors.

2. OBJECTIVES OF THE RESEARCH

1. To study the total factor productivity of wheat in Nigeria.
2. To examine the factors affecting the supply of wheat in Nigeria

3. MATERIAL AND METHODS

Data source:

Table 3.1. Variables used in the Analysis

Variables	Objectives	Sources
Wheat Production	1,2	FAO
Wheat Area	1	FAO
Labor Index	1	World Bank
Machinery use Index	1	World Bank
Capital index	1	World Bank
Irrigation index	1	World Bank
Fertilizer use Index	1	World Bank
Climatic Data	2	FAO
Import Price	2	FAO
Maize Price	2	FAO
Inflation	2	FAO

Augmented Dickey-fuller Tests

The ADF test is classified as a 'Unit Root Test', which is the right way to determine the stationarity of a time series, developed by Said and Dickey (1984). Unit root is a characteristic of a time series that makes it non-stationary.

Tonqvist-Theil Index of Productivity

The Total Factor Productivity (TFP) measures the efficiency with which inputs are converted into output, accounting for factors beyond just labor and capital. The Tonqvist-Theil index is an excellent index that is exact for the linear homogeneous translog production function. A further advantage of the Tornqvist-Theil index is that it accounts for changes in the quality of inputs. Because current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates (Rosegrant & Evenson, 1995).This method used by researchers across the globe such as (Gocic & Trajkovic, 2013; Polisetty & Paidipati, 2020; Yue *et al.*, 2019) among others.

$$In\left(\frac{TFPt}{TFPt-1}\right) = \left(\sum_{i=1}^{n}\frac{1}{2}(s_{it}+s_{i\,(t-1)})\,In\left(\frac{Y_{it}}{Y_{i(t-1)}}\right)\right) - \left(\sum_{j=1}^{m}\frac{1}{2}(Wj_t+W_{j(t-1)})\,In\left(\frac{X_{jt}}{X_{j(t-1)}}\right)\right)$$

Where; TFP_t and TFP_{t-1} are the total factor productivity at time t and t-1. Y_{it} and Y_{it-1} is the quantities of i output at t and t-1. X_{jt} and X_{jit-1} is the quantities of j output at t and t-1. S_{it} and S_{it-1} is the share of output i at t and t-1. W_{jt} and W_{jt-1} is the share of input j at t and t-1. n and m are number of inputs and the number of outputs.

Auto Regressive Distributed Lags (ARDL)

This study presents the econometric specification using the ARDL model proposed by Pesaran et al. (2001). The benefit of this model is that it helps to simultaneously study the short-run and long-run effects of the independent variable on the dependent variable. Moreover, it can also be used when variables are integrated of either order zero or one. The short-run and long-run relationship between the variables is given by this equation:

$$\triangle PROQ\text{t} = \alpha + \sum_{i=1}^{p-1} \beta_{\text{i}} \triangle PROQ_{\text{t-I}} + \sum_{j=0}^{q1} \gamma j \triangle WPR_{\text{t-j}} + \sum_{k=0}^{q2} \delta_{\text{k}} \triangle CLI_{\text{t-k}} + \sum_{l=1}^{q3} \eta_{\text{l}} \triangle MPR_{\text{t-l}} + \sum_{m=0}^{q4} \theta_{\text{m}} \triangle CPI_{\text{t-m}} + \varepsilon_{\text{t}}$$

The first set of terms in the equation includes $\triangle PORQt$ as the change in the production quantity of wheat at a time t, representing the dependent variable, α is the constant term. $\sum_{i=1}^{p-1} \beta_i \triangle PROQ_{t\text{-}I}$ is the lagged change in production quantity as the autoregressive component of the model. $\sum_{j=0}^{q1} \gamma j \triangle WPR_{t\text{-}j}$ is the lagged change in the wheat price. $\sum_{k=0}^{q2} \delta_k \triangle CLI_{t\text{-}k}$ is the lagged change in climate variables . $\sum_{l=1}^{q3} \eta_l \triangle MPR_{t\text{-}l}$ is the lagged change in the maize price as substitute . $\sum_{m=0}^{q4} \theta_m \triangle CPI_{t\text{-}m}$ is the lagged change in the consumer price index reflecting the socioeconomic status of the farmer. ε_t is the error term, capturing the random shocks not accounted for by other variables in the model. All the variables were transformed into their natural logarithm before fitting the ARDL model.

Tools used

- Python
- R software
- E-VIEWS

4. RESULT AND DISCUSSION

Table 4.1 Total Factor Productivity (TFP) Variables

Decades	Average Area	Labor	Irrigation	Fertilizer	Machinery	Capital	Output
1982-1991	43400	74.45	74.45	78	61	24	68300
1992-2001	33020	91	91	76	88	33	58740
2002-2011	52404.5	102	102	83	104	60	66044
2012-2022	68242.18	105	100	153	101	101	80527

Table 4.2 TFP Result (Tonqvist-Theil Index)

Year	TFP	Year	TFP	Year	TFP	Year	TFP
1983	0.71	1993	1.72	2003	1.05	2013	0.98
1984	0.91	1994	1.01	2004	1.03	2014	1.30
1985	1.23	1995	0.94	2005	1.03	2015	0.77
1986	0.96	1996	0.94	2006	1.02	2016	0.99
1987	0.98	1997	1.29	2007	1.49	2017	1.67
1988	0.64	1998	0.76	2008	0.98	2018	1.02
1989	0.96	1999	1.01	2009	1.01	2019	0.98
1990	0.70	2000	0.70	2010	0.89	2020	0.65
1991	1.44	2001	0.70	2011	0.81	2021	1.03
1992	1.11	2002	1.01	2012	0.85	2022	0.98
Average	0.96	-	1.01	-	1.02	-	1.04

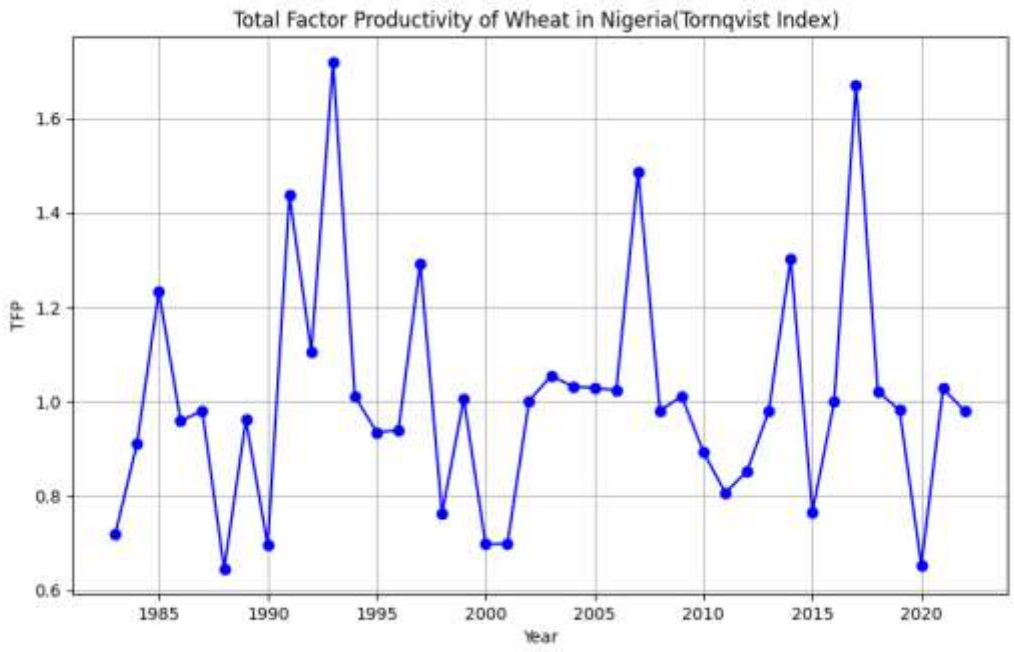


Figure 4.1 Total Factor Productivity of Wheat Crop in Nigeria (1982-2022)

From Table 4.8, between 1983 and 2022, Nigeria's wheat Total Factor Productivity (TFP) exhibited a trend of fluctuation, with an average TFP ranging from 0.96 to 1.04 throughout all of the decades. This points to gradual increases in production over time, with notable decreases in 1988 (0.64) and 2020 (0.65) and peaks in 1993 (1.72) and 2007 (1.49). The relative stability of the early 1990s and mid-2000s may be attributed to improvements in agricultural inputs and

supportive policies, whereas the volatility of the 1980s and recent years may be attributed to infrastructure challenges inconsistent policies, and other influences such as climate change.

The lack of mechanization and the slow adoption of modern farming techniques were identified as major obstacles to agricultural output in early research, such as (Kimmage, 1991). This issue is still present in more recent work by (Olomola & Nwafor, 2018).

This contributes to the understanding of why productivity fluctuated during the 1980s and early 1990s, even if it improved in the mid-2000s due to government reforms and subsidies. Inadequate investment and climate variability are two more recent studies which point to significant obstacles to increasing TFP.

Usman, (2007) highlights how unpredictable rainfall patterns, which are linked to the diminishing TFP trend starting in 2015, are one effect of climate change on wheat output. Although mechanization and input availability were enhanced by reforms in the late 1990s and early 2000s, as noted by (Asiva Noor Rachmayani, 2015; Castelein et al., 2022; O. J., 2015) the industry has not reached its full potential.

According to Adeola et al., (2024); Eswaran & Kotwal, (2006), governance problems and a lack of funding prevent technology solutions from being fully deployed, which keeps TFP below expectations. This review of the literature demonstrates that, despite certain advancements, Nigeria's wheat industry still faces significant challenges such as inconsistent policy, poor infrastructure, and the consequences of climate change, which hinder the nation's capability to increase its total food production significantly over the long run.

Supply Response Analysis

Table 4.3 Unit-Root Test Result

Variables	Estimated ADF	ADF-1%	ADF-5%	P-value
CPI	-3.63	-3.61	-2.93	0.0095
PRQ	-3.58	-3.61	-2.93	0.0106
HUM	-2.95	-3.61	-2.93	0.049
TEM	-3.74	-3.61	-2.93	0.0071
PRC	-5.05	-3.61	-2.93	0.0002
MPR	2.61	-3.67	-2.96	1
IPR	-1.81	-3.61	-2.93	0.3682
D(MPR)	-4.2	-3.67	-2.96	0.0026
D(IPR)	-7.73	-3.61	-2.93	0

Table 4.3 presents the Augmented Dickey-Fuller (ADF) test results which indicate that multiple variables are stationary at the 5% significance level, since their estimated ADF statistics are less than the crucial values at both 1% and 5%. The Consumer Price Index (CPI), Production Quantity (PRQ), Human Humidity (HUM), Temperature (TEM), and Precipitation (PRC) are all stationary, with p-values < 0.05. However, the Maize Price (MPR) and Wheat Price (WPR) show non-stationary levels, as evidenced by p-values of 1 and 0.3682, respectively. When D (MPR) and D (WPR) are differentiated, they become stationary, as seen by significantly

reduced ADF values and p-values of 0.0026 and 0, respectively. It also implies that these variables are integrated of order 1 (I (1)), which means they become stationary after the first differencing.

Table 4.4 Short-Run Estimates

variables	coefficient	std. Error	t-Statistic	P-value
C	208.1555	60.10668	3.463101	0.0028
DPRQ(-2)	0.310062	0.14501	2.138208	0.0465
WPR (-1)	0.660118	0.208908	3.159849	0.0054
HUM (-1)	-57.49236	16.87448	-3.407059	0.0031
MPR (-1)	0.311367	0.11452	2.718881	0.0141
TEM	0.215644	0.303521	0.710473	0.4865
PRC (-1)	3.03782	1.791565	1.695623	0.1072
CPI	0.12486	0.117176	1.065574	0.3007
D(MPR (-2))	0.38829	0.171833	2.25969	0.0365
CointEq(-1)*	-0.433277	0.607923	-6.378919	0

Table 4.5 F-Bound Test for Cointegration

	Value	Lower Bound I(0)	Upper Bound I(1)	confidence level
F-Statistics	4.36	2.12	3.23	10%
k	6	2.45	3.61	5%
		2.75	3.99	2.50%
		3.15	4.43	1%

Table 4.6 Long Run Estimates

Variables	coefficient	std. Error	t-Statistic	P-value
WPR	1.523547	1.157977	1.3115696	0.2048
HUM	-12.6919	10.4811	-1.294794	0.2118
TEM	0.497704	0.838099	0.593848	0.56
PRC	7.011264	7.201074	0.973641	0.3431
CPI	0.288176	0.390091	0.738741	0.4696
MPR	0.718632	0.520612	1.380359	0.1844

Table 4.7 Residual Check

Breuch-Godfrey Test	**Serial Correlation Test**	**P-value**
F-statistic	0.032853	0.9677
Obs*R-squared	0.155411	0.9252
Breuch-Pagan Test	Heteroscedasticity Test	P-value
F-statistic	0.733436	0.7458
Obs*R-squared	16.58168	0.6182
ARCH effect test	Time-Volatility	P-value
F-statistic	0.009844	0.9215
Obs*R-squared	0.010404	0.9188
Jarque-Bera Test	Normality	P-value
T-statistic	0.711857	0.700523

The ARDL model results for wheat cultivation in Nigeria in Table 4.4 indicate distinct both short- and long-run dynamics. In the short run, lagged wheat production (DPRQ (-2)) has a significant positive effect, with a two-period lag (p = 0.0465), suggesting that historical production levels influence current output. Wheat prices (WPR -1) also have a positive effect (p = 0.0054), showing that higher prices encourage more output. Humidity (HUM -1) reduces productivity (p = 0.0031), most likely due to poor growing conditions produced by high wetness. The positive influence of maize prices (MPR-1) (p = 0.0141) supports crop substitution effects, with higher maize prices potentially leading to increased wheat output. Temperature (TEM) and inflation (CPI) have no significant short-term effects.

The F-statistic (4.36) is above the upper bound at the 5% level (3.61) from Table 4.5, indicating a long-run relationship (co-integration) between wheat production and the explanatory variables. Wheat production is not considerably affected over the long run by any of the explanatory variables (wheat price, humidity, temperature, price of maize, or inflation) from Table 4.5. Stability over time is ensured by the error correction term (-0.433, p = 0.000), which shows that deviations from long-run equilibrium are corrected at a rate of 43.3% every period.

The short-run results are supported by recent studies, particularly when it comes to price responsiveness. According to Balint, (2024), producers quickly consider price rises and other market incentives when deciding how much to produce to maximize their profits. Additionally, A. Ali et al., (2023); and Shah et al., (2024)stress that environmental factors such as humidity may significantly hamper agricultural productivity in the near term, particularly in regions like Nigeria that rely heavily on rainfall. The crop substitution theory, according to which farmers modify their crop selections based on relative profitability, is compatible with the effects of maize prices (Nkhata et al., 2021).

Some studies indicate that climatic factors like temperature and humidity might have cumulative effects on agricultural output over time, as opposed to the long-run findings, Hassan, (2010)for example, argues that long-run production trends are typically shaped by climate variables, especially when persistent climate change is present. Similarly, Anderson, (2022) finds that, while prices may lose predictive power in the long run due to market

adjustments, natural stressors like extensive droughts or floods continue to affect yields over extended periods.

Ultimately, the diagnostic findings from Table 4.6, verify that there is no serial correlation, heteroscedasticity, time-varying volatility, or non-normality in the residuals of the ARDL model. These diagnostics corroborate the credibility of the estimated short-run and long-run interactions for wheat agriculture in Nigeria.

5. CONCLUSION AND RECOMMENDATION

The empirical findings of this study provide valuable insights into the dynamics of wheat production in Nigeria. Total Factor Productivity exhibited marginal growth over the study period, punctuated by periods of both efficiency gains and declines. These trends mirror the interplay between policy shifts, climatic variability, and infrastructural development.

The supply response analysis revealed that wheat production is significantly influenced by price signals and environmental factors in the short run, notably wheat and maize prices, as well as humidity levels. However, the lack of significant long-run effects implies the presence of structural limitations within the sector, including weak policy coherence, insufficient investment in agricultural technology, and inadequate adaptation to climate risks. The stable and significant error correction mechanism suggests the possibility of long-term improvements if systematic interventions are sustained.

Therefore, to enhance wheat productivity in Nigeria, there is an urgent need for an integrated and consistent agricultural policy framework that fosters private and public sector collaboration, improves access to agricultural inputs, and promotes mechanization. Investments in research and development should prioritize the breeding and dissemination of climate-resilient wheat varieties, alongside the expansion of irrigation infrastructure to mitigate the impact of erratic weather patterns. Furthermore, targeted subsidies and credit schemes could incentivize farmers to adopt modern technologies and improve input efficiency.

Future research should explore the interaction effects between specific inputs such as the synergy between fertilizer application and irrigation on productivity outcomes. Comparative studies across agro-ecological zones within and beyond Nigeria could also provide broader insights into best practices and contextual adaptability. Additionally, integrating climate change projection models into productivity analysis would be instrumental in formulating long-term adaptive strategies for the wheat sector in Nigeria.

Conflict of Interest Statement
the authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability Statement
the data that support the findings of this study are available from the Food and Agricultural Organization (FAO) database [https://www.fao.org/faostat], which is publicly accessible. Other data were sourced from World Bank.

Ethics Statement
This study used secondary data and did not involve any human participants or animals; therefore, ethical approval was not required.

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ORGANIC FARMING AND ITS ROLE IN SUSTAINABLE AGRICULTURE

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ABSTRACT

Organic farming has emerged as a vital approach to sustainable agriculture, promoting environmental health, biodiversity, and long-term soil fertility while reducing dependence on synthetic chemicals. This paper explores the principles and practices of organic farming and evaluates its contributions to sustainability goals, including improved soil quality, water conservation, and reduction of greenhouse gas emissions. The review highlights the benefits of organic methods in enhancing ecosystem services and resilience against climate change. Additionally, challenges such as lower yields, certification costs, and market access are discussed. The paper concludes by emphasizing the need for supportive policies, farmer education, and research innovations to scale up organic farming as a sustainable alternative that balances productivity with ecological stewardship.

Keywords: Organic farming, sustainable agriculture, soil health, biodiversity, environmental conservation, climate resilience, eco-friendly practices, food security.

INTRODUCTION

Organic farming is an agricultural system that emphasizes the use of natural inputs and processes to enhance soil fertility, conserve biodiversity, and maintain ecological balance while producing food (Reganold & Wachter, 2016). Unlike conventional farming, which relies heavily on synthetic fertilizers, pesticides, and genetically modified organisms, organic farming practices avoid chemical inputs and focus on crop rotation, composting, biological pest control, and the use of organic fertilizers (Gomiero, Pimentel, & Paoletti, 2011). This approach aims to promote sustainable agriculture by fostering long-term soil health, reducing environmental pollution, and supporting resilient agro-ecosystems.

Sustainable agriculture addresses the growing global challenges of environmental degradation, climate change, and food security by integrating economic viability with ecological preservation and social equity (Pretty, 2008). Organic farming contributes significantly to these goals by improving soil organic matter, enhancing biodiversity, and minimizing greenhouse gas emissions associated with intensive chemical use (Tuomisto, Hodge, Riordan, & Macdonald, 2012). Additionally, organic farming systems have been linked to improved water retention and reduced contamination of water bodies, which are critical for sustaining agriculture in the face of climate variability (Seufert, Ramankutty, & Foley, 2012). Despite its benefits, organic farming faces challenges such as generally lower yields, certification complexities, and market accessibility issues (Ponisio et al., 2015). However, growing consumer demand for organic products and increasing policy support worldwide suggest a positive trajectory for organic farming as a core component of sustainable agriculture.

PRINCIPLES OF ORGANIC FARMING

Organic farming is guided by core principles that focus on ecological balance, sustainability, and the avoidance of synthetic inputs. These principles ensure that farming practices support soil health, biodiversity, and environmental conservation while producing nutritious food (IFOAM, 2014).

Health: Organic farming prioritizes the health of soil, plants, animals, humans, and the planet as interconnected systems. Maintaining soil fertility through natural processes ensures the production of healthy crops without harmful chemical residues (Reganold & Wachter, 2016).

Ecology: Farming practices are designed to work with natural ecosystems rather than against them. Organic systems promote biodiversity, nutrient cycling, and ecological balance by using crop rotations, intercropping, cover crops, and biological pest control to reduce pest outbreaks and soil erosion (Gomiero et al., 2011).

Fairness: Organic farming emphasizes fairness in the relationships between farmers, consumers, and society. It supports equitable labor conditions, community well-being, and transparency in production and marketing (IFOAM, 2014).

Care: Stewardship of the land requires careful management to protect natural resources for future generations. This principle encourages precaution and responsibility in farming decisions, avoiding practices that may harm the environment or human health (Pretty, 2008).

Key organic practices stemming from these principles include the use of organic fertilizers such as compost and manure, biological nitrogen fixation through legumes, minimal soil disturbance, and prohibition of synthetic pesticides, herbicides, and genetically modified organisms (GMOs)

(Seufert et al., 2012). By adhering to these principles, organic farming fosters resilient agricultural systems that can adapt to climate variability and reduce environmental degradation.

BENEFITS OF ORGANIC FARMING FOR SUSTAINABLE AGRICULTURE

Organic farming offers numerous benefits that align closely with the goals of sustainable agriculture by promoting environmental health, economic viability, and social well-being.

Soil Health Improvement

Organic farming enhances soil structure and fertility through practices such as compost application, green manuring, and crop rotation. These methods increase soil organic matter, microbial diversity, and nutrient cycling, which lead to improved soil productivity and resilience (Lori, Symnaczik, Mäder, De Deyn, & Gattinger, 2017). Healthier soils also improve water retention, reducing erosion and mitigating drought effects (Reganold & Wachter, 2016).

Biodiversity Conservation

By avoiding synthetic chemicals and fostering diversified cropping systems, organic farming supports higher levels of biodiversity both above and below ground. Increased biodiversity contributes to ecosystem stability, pest control, and pollination services essential for crop production (Bengtsson, Ahnström, & Weibull, 2005). Studies have shown that organic farms host more species of plants, insects, and soil organisms compared to conventional farms (Hole et al., 2005).

Reduced Environmental Pollution

Organic farming eliminates the use of synthetic pesticides and fertilizers, significantly reducing chemical runoff and groundwater contamination. This minimizes harm to aquatic ecosystems and protects human health from pesticide exposure (Tuomisto, Hodge, Riordan, & Macdonald, 2012). Moreover, organic practices reduce fossil fuel use by avoiding synthetic input manufacturing, lowering agriculture's carbon footprint (Gomiero, Pimentel, & Paoletti, 2011).

Climate Change Mitigation

Organic systems tend to sequester more carbon in soil due to higher organic matter inputs and reduced soil disturbance. This sequestration contributes to mitigating greenhouse gas emissions (Powlson et al., 2014). Additionally, organic farming's emphasis on local inputs and energy efficiency supports climate resilience.

Economic and Social Benefits

Though yields may be lower in some cases, organic farming can improve farmers' income through premium product prices and reduced input costs (Ponisio et al., 2015). It also encourages rural development by promoting local knowledge, community engagement, and sustainable livelihoods.

IMPACT ON SOIL HEALTH AND BIODIVERSITY

Organic farming has a profound positive impact on both soil health and biodiversity, which are crucial components of sustainable agricultural ecosystems.

Soil Health

Organic farming enhances soil quality by increasing organic matter content, improving soil structure, and fostering a diverse and active microbial community. The use of compost, green

manures, and crop rotations replenishes essential nutrients and stimulates beneficial soil microorganisms, which in turn promote nutrient cycling and disease suppression (Lori, Symnaczik, Mäder, De Deyn, & Gattinger, 2017). Reduced reliance on synthetic chemicals prevents the degradation of soil biota and maintains soil fertility over the long term (Gomiero, Pimentel, & Paoletti, 2011). Moreover, organic soils typically exhibit better water infiltration and retention, helping mitigate drought stress and erosion (Reganold & Wachter, 2016).

Biodiversity

Organic farming supports greater biodiversity at multiple levels—soil organisms, plants, insects, birds, and other wildlife. The avoidance of synthetic pesticides and herbicides allows beneficial insects and pollinators to thrive, enhancing ecosystem services such as natural pest control and pollination (Bengtsson, Ahnström, & Weibull, 2005). Diverse cropping patterns and habitat conservation on organic farms further contribute to the richness and abundance of species (Hole et al., 2005). Soil biodiversity, including earthworms and mycorrhizal fungi, plays a vital role in nutrient cycling and soil structure improvement, reinforcing the overall resilience of organic systems (Lori et al., 2017).

WATER CONSERVATION AND ENVIRONMENTAL PROTECTION

Organic farming plays a significant role in conserving water resources and protecting the environment, which are essential for sustainable agriculture.

Water Conservation

Organic practices improve soil structure and increase organic matter content, which enhances the soil's water-holding capacity and infiltration rates. This means organic soils can retain more moisture and reduce surface runoff, making water use more efficient and reducing the need for irrigation (Reganold & Wachter, 2016). The use of cover crops and mulching further reduces evaporation losses and maintains soil moisture levels (Lal, 2020). By promoting healthy soils and reducing compaction, organic farming helps mitigate drought impacts and supports crop resilience during dry periods (Drinkwater, Wagoner, & Sarrantonio, 1998).

Environmental Protection

Organic farming reduces the contamination of water bodies by eliminating synthetic pesticides and fertilizers, which are common sources of nutrient runoff and water pollution in conventional agriculture (Tuomisto, Hodge, Riordan, & Macdonald, 2012). This decrease in chemical inputs protects aquatic ecosystems, reduces eutrophication, and safeguards biodiversity in surrounding habitats (Gomiero, Pimentel, & Paoletti, 2011). Furthermore, organic farming practices contribute to lower greenhouse gas emissions and reduced fossil fuel use, promoting overall environmental sustainability (Seufert, Ramankutty, & Foley, 2012).

CHALLENGES AND LIMITATIONS OF ORGANIC FARMING

While organic farming offers numerous environmental and health benefits, it also faces several challenges and limitations that can affect its widespread adoption and productivity.

Lower Yields and Productivity

One of the primary concerns with organic farming is generally lower crop yields compared to conventional agriculture. Studies indicate that organic yields can be 20-25% lower on average, primarily due to constraints in nutrient availability and pest management (Seufert, Ramankutty, & Foley, 2012). This yield gap may affect food security, especially in regions with high population pressure.

Pest and Disease Management

Organic farmers rely on natural pest control methods, which may be less effective or slower to act compared to synthetic pesticides. This can result in higher vulnerability to pest outbreaks or diseases, leading to crop losses (Hillocks, 2012). The absence of chemical inputs demands more labor-intensive practices, increasing production costs.

Labor Intensity and Costs

Organic farming often requires more manual labor for weed control, soil preparation, and monitoring, which can increase operational costs (Lampkin & Measures, 2015). The higher labor requirement and the need for specialized knowledge can limit adoption, particularly for small-scale or resource-poor farmers.

Certification and Market Barriers

Obtaining organic certification involves strict compliance with standards, record-keeping, and inspection, which can be time-consuming and costly for farmers (Willer & Lernoud, 2019). Additionally, the premium prices of organic products may not always be accessible to all consumers, limiting market demand in certain regions.

PROSPECTS AND INNOVATIONS IN ORGANIC FARMING

Organic farming is increasingly recognized as a key strategy for sustainable agriculture, addressing environmental degradation, food safety, and climate resilience. The future prospects of organic farming are promising, bolstered by technological innovations and supportive policies.

Integration of Smart Technologies

Emerging technologies such as Internet of Things (IoT), drones, and remote sensing are being integrated into organic farming to enhance precision in monitoring soil health, moisture levels, and pest management without relying on chemicals (Sharma et al., 2020). Smart irrigation systems help optimize water use, vital for resource-efficient organic practices.

Advances in Biofertilizers and Biopesticides

Innovations in biofertilizers and biopesticides are improving the efficacy and scalability of organic inputs. Microbial formulations that enhance nutrient uptake and pest resistance are being developed, reducing dependence on synthetic fertilizers and pesticides (Singh et al., 2019).

Use of Artificial Intelligence (AI) and Machine Learning

AI-driven tools are being used to predict pest outbreaks, optimize crop rotation, and improve yield forecasting in organic farming systems. Machine learning models can analyze large datasets to tailor organic management practices to specific local conditions (Liakos et al., 2018).

Vertical and Urban Organic Farming

With rising urbanization, vertical farming combined with organic principles offers a sustainable solution to produce fresh, chemical-free food in limited spaces. Hydroponics and aeroponics are being adapted for organic inputs, reducing land use and transport emissions (Despommier, 2013).

Genetic Improvement of Organic Crop Varieties

Breeding crop varieties specifically suited to organic conditions such as improved nutrient use efficiency and pest resistance—can help close the yield gap with conventional farming (Mäder et al., 2007). Participatory plant breeding involving farmers accelerates adoption.

Policy and Market Evolution

Increasing consumer demand for organic products is driving market expansion and encouraging investment in organic supply chains. Policies that support certification, subsidies for organic inputs, and research funding are expected to grow (Willer & Lernoud, 2023).

CONCLUSION

Organic farming holds significant promise for advancing sustainable agriculture by promoting environmental health, biodiversity, and food safety. With the integration of smart technologies, advances in biofertilizers, and AI-driven tools, organic farming is becoming more efficient and scalable. Innovations such as urban vertical farming and development of organic-specific crop varieties further enhance its potential to meet growing food demands sustainably. Coupled with supportive policies and rising consumer demand, these trends indicate a positive future for organic agriculture as a cornerstone of resilient and eco-friendly food systems.

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WATER MANAGEMENT TECHNIQUES FOR DROUGHT PRONE AGRICULTURAL AREAS

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ABSTRACT

Water scarcity poses a significant challenge to agricultural productivity, especially in drought-prone regions where erratic rainfall and depleting groundwater resources threaten food security and rural livelihoods. This research explores innovative and sustainable water management techniques tailored to such vulnerable areas. It examines the effectiveness of methods including drip and sprinkler irrigation, rainwater harvesting, mulching, soil moisture conservation, and the use of drought-resistant crop varieties. The study also highlights the role of digital tools like remote sensing and IoT-enabled smart irrigation systems in optimizing water use. Through case studies and field data analysis, the research aims to identify best practices and scalable models that enhance water-use efficiency while maintaining agricultural output. The findings are intended to support policymakers, farmers, and agricultural planners in adopting context-specific solutions to build climate-resilient farming systems.

Keywords: Water management, drought-prone agriculture, drip irrigation, rainwater harvesting, soil moisture conservation

Introduction

Agriculture is a major consumer of freshwater resources worldwide, accounting for approximately 70% of global freshwater withdrawals (FAO, 2021). In drought-prone agricultural areas, water scarcity severely limits crop production and threatens food security, particularly in regions dependent on rain-fed agriculture. The increasing frequency and intensity of droughts due to climate change have exacerbated the challenges faced by farmers in these vulnerable areas (IPCC, 2022). Efficient water management is therefore critical to sustaining agricultural productivity and ensuring the livelihoods of rural populations. Traditional water management practices such as rainwater harvesting and mulching have been practiced for centuries to conserve soil moisture and optimize water availability (Kumar & Singh, 2019). However, these methods alone may not suffice to address the growing water demands under changing climatic conditions. Recent advancements in irrigation technologies, including drip and sprinkler systems, offer promising solutions by enhancing water-use efficiency and reducing wastage (Jat et al., 2020). Furthermore, the integration of digital technologies like Internet of Things (IoT) sensors and remote sensing tools has enabled precision irrigation, where water application is tailored to crop needs in real-time, maximizing efficiency (Patel et al., 2021). This research aims to analyze and evaluate various water management techniques suitable for drought-prone agricultural regions, focusing on both traditional and modern approaches. Through a review of literature and case studies, the study seeks to identify best practices and propose integrated strategies to improve water sustainability and resilience in agriculture.

Overview of Drought-Prone Agricultural Areas

Drought-prone agricultural areas are regions characterized by low and irregular rainfall, high evapotranspiration rates, and limited water availability, which collectively create harsh conditions for crop cultivation (Vicente-Serrano et al., 2020). These areas are predominantly found in arid and semi-arid zones, covering significant parts of continents such as Africa, Asia, Australia, and parts of the Americas (Wilhite et al., 2014). The vulnerability of these regions to drought is heightened by soil degradation, over-extraction of groundwater, and increasing population pressures that intensify competition for scarce water resources (Zhang et al., 2021).

The socio-economic impact of drought in these agricultural landscapes is profound. Crop failures due to insufficient water supply lead to food insecurity, income loss, and increased poverty among rural communities who largely depend on farming for their livelihood (FAO, 2022). Moreover, droughts exacerbate land degradation processes such as desertification, reducing the long-term productive capacity of the land (UNCCD, 2017). Understanding the spatial and temporal dynamics of drought in these regions is therefore critical to designing effective water management and drought mitigation strategies. The complex interaction of climatic, hydrological, and human factors shapes the challenges faced by drought-prone agricultural areas. Variability in rainfall patterns, often resulting in prolonged dry spells and unpredictable monsoons, creates uncertainty for farmers planning sowing and harvesting cycles (Dai, 2013). Additionally, traditional reliance on rain-fed agriculture without adequate irrigation infrastructure compounds the risks of drought-induced crop failure (Rockström et al., 2010). Therefore, targeted interventions to improve water use efficiency and enhance drought resilience are essential to sustain agricultural productivity in these vulnerable zones.

Traditional Water Management Practices

Traditional water management practices have been the cornerstone of agricultural sustainability in drought-prone regions for centuries. These methods focus on conserving and efficiently

utilizing available water resources by adapting to local environmental conditions and indigenous knowledge systems. One of the most widely used traditional techniques is rainwater harvesting, which involves collecting and storing rainwater from rooftops, catchment areas, or small reservoirs to be used during dry periods. This practice reduces dependency on erratic rainfall and supplements irrigation needs (Alaerts & Vairavamoorthy, 2013). Mulching is another essential technique used to conserve soil moisture by covering the soil surface with organic or inorganic materials. Mulching helps reduce evaporation, suppress weed growth, and improve soil fertility, thereby enhancing water retention capacity in agricultural fields (Kumar & Singh, 2019). Similarly, contour bunding and terracing are soil and water conservation methods that reduce runoff, increase water infiltration, and prevent soil erosion on sloped lands (Sreedevi et al., 2018).

Traditional check dams and small-scale water harvesting structures have also played a significant role in capturing surface runoff, recharging groundwater, and providing supplemental irrigation water in arid zones (Palanisami et al., 2020). These community-managed water systems often involve collective action, fostering social cohesion and shared responsibility for sustainable resource management (Fernandez, 2014). While these traditional practices are cost-effective and environmentally friendly, their efficiency can be limited by changing climatic patterns and increased water demand. Nonetheless, integrating traditional methods with modern technologies offers a promising pathway toward sustainable water management in drought-prone agricultural areas.

Modern Water Management Techniques

Modern water management techniques have transformed agricultural practices by enhancing water-use efficiency and mitigating the impacts of drought, particularly in water-scarce and drought-prone regions. Among these, drip irrigation stands out as a highly efficient method, delivering water directly to the plant root zone through a network of tubes and emitters. This precision watering reduces water wastage due to evaporation and runoff, leading to water savings of up to 50% compared to traditional flood irrigation (Jat et al., 2020). Similarly, sprinkler irrigation systems distribute water through pressurized pipes and nozzles, mimicking natural rainfall and providing uniform water coverage, which is beneficial for a variety of crops and terrains (Patel et al., 2019). The development and adoption of drought-resistant crop varieties represent another key strategy in modern water management. These crops are genetically bred or biotechnologically enhanced to tolerate water stress, thus maintaining yield levels during periods of limited water availability (Ashraf & Foolad, 2013). This biological approach complements physical water-saving techniques by reducing crop water demand.

Furthermore, the integration of digital technologies such as Internet of Things (IoT)-based smart irrigation systems and remote sensing has revolutionized water management. IoT sensors monitor soil moisture, weather conditions, and crop water requirements in real-time, enabling automated and optimized irrigation scheduling (Patel et al., 2021). Remote sensing technologies provide large-scale data on soil moisture and vegetation health, assisting farmers and policymakers in decision-making for water allocation and drought preparedness (Zhang et al., 2020). These modern techniques, when combined with traditional practices, offer a comprehensive approach to water management in drought-prone agricultural areas, promoting sustainability and climate resilience.

Role of Technology in Water Management

Technology plays a pivotal role in modernizing water management practices, especially in drought-prone agricultural regions where efficient use of scarce water resources is critical.

Advances in digital technologies, sensor networks, and data analytics have enabled more precise, timely, and sustainable water management solutions. One of the most significant technological advancements is the use of Internet of Things (IoT) devices for real-time monitoring of soil moisture, weather conditions, and crop water requirements. These IoT-based smart irrigation systems automate water delivery based on actual needs, thereby minimizing wastage and optimizing water use efficiency (Patel et al., 2021). Coupled with remote sensing technologies such as satellite imagery and drones, farmers can monitor large agricultural landscapes to assess drought stress, soil moisture variability, and crop health remotely, facilitating informed decision-making (Zhang et al., 2020).

Geographic Information Systems (GIS) have also been instrumental in water resource management, enabling spatial analysis of water availability, watershed management, and identification of vulnerable zones. GIS combined with hydrological modeling supports planners and policymakers in developing sustainable water allocation strategies under changing climatic scenarios (García et al., 2017). Furthermore, artificial intelligence (AI) and machine learning algorithms are increasingly being applied to predict drought events, optimize irrigation scheduling, and manage water distribution networks efficiently (Liakos et al., 2018). These predictive models enhance early warning systems and help mitigate the adverse impacts of water scarcity on agriculture. Overall, the integration of these technological tools fosters precision agriculture, enhances drought resilience, and promotes sustainable water management practices essential for food security in drought-prone areas.

Case Studies and Field Applications

Practical implementations of water management techniques in drought-prone agricultural areas provide valuable insights into their effectiveness and adaptability. Several case studies worldwide demonstrate the integration of traditional knowledge with modern technology to optimize water use and improve crop productivity. In India’s semi-arid region of Rajasthan, the Watershed Development Program combined traditional water harvesting structures such as check dams and johads with modern soil and water conservation techniques. This integrated approach significantly improved groundwater recharge and enhanced agricultural productivity in drought-affected villages (Bhatt et al., 2019). The community-based management of these water resources also fostered local participation and long-term sustainability.

In Kenya, the adoption of drip irrigation systems in smallholder farms within drought-prone areas has shown remarkable improvements in water use efficiency and crop yields. Farmers using these systems reported up to 40% water savings and increased income from higher-quality produce (Mwangi & Ouma, 2021). The success was attributed to capacity-building programs that educated farmers on system installation and maintenance. Another notable example is from the state of California, USA, where IoT-enabled smart irrigation systems have been deployed in vineyards and orchards. These systems use soil moisture sensors and weather forecasts to automate irrigation, reducing water consumption by approximately 30% without compromising crop quality (Jones et al., 2020). The integration of remote sensing data allowed large-scale monitoring and precise water allocation, enhancing drought resilience.

In Australia, the Drought Resilience Adoption and Innovation Hub promotes the use of drought-tolerant crop varieties alongside water-saving irrigation technologies in drought-prone farming zones. Pilot projects have demonstrated improved farm profitability and resource sustainability, providing models for scaling up in similar agro-climatic regions globally (Smith et al., 2022). These case studies underline the importance of tailoring water management practices to local conditions and engaging stakeholders in participatory approaches to ensure successful outcomes in drought-prone agricultural landscapes.

Challenges and Limitations

Despite significant advances in water management techniques, several challenges and limitations hinder their widespread adoption and effectiveness in drought-prone agricultural areas. One major challenge is the high initial cost and maintenance requirements associated with modern technologies like drip irrigation systems and IoT-based smart irrigation. Smallholder farmers, who constitute the majority in many drought-affected regions, often face financial constraints that limit access to such innovations (Gebregziabher et al., 2020).

Another limitation is the lack of technical knowledge and training required to operate and maintain sophisticated water management systems. Without proper capacity building, farmers may struggle to utilize these technologies efficiently, leading to underperformance and resource wastage (Patel et al., 2021). Furthermore, technological solutions may not always be tailored to local socio-economic and environmental contexts, which can reduce their relevance and adoption rates (Fernandez, 2014).

Water governance and institutional issues also pose significant barriers. Fragmented water management policies, lack of coordination among stakeholders, and inadequate support from governmental agencies can impede the implementation of integrated water management strategies (García et al., 2017). In many regions, competing demands for water from agriculture, industry, and households exacerbate scarcity and complicate sustainable management.Additionally, climate variability and unpredictability present inherent uncertainties that challenge water management planning. Extreme drought events and irregular rainfall patterns can overwhelm existing infrastructure and adaptive capacities, reducing the resilience of farming systems (Ashraf & Foolad, 2013). Addressing these challenges requires a holistic approach that combines technological innovation, capacity building, community participation, and supportive policies to ensure sustainable water management in drought-prone agricultural landscapes.

Policy Recommendations and Future Directions

To enhance water management in drought-prone agricultural areas, comprehensive policy interventions and future-focused strategies are essential. Policymakers should prioritize investment in affordable and scalable water-saving technologies, ensuring that smallholder farmers have access to drip irrigation, sprinkler systems, and IoT-enabled smart irrigation solutions through subsidies, microfinancing, and public-private partnerships (Gebregziabher et al., 2020). Capacity building and farmer education programs must be strengthened to improve technical know-how and system maintenance skills, facilitating better adoption and sustained use of modern water management practices (Patel et al., 2021). Extension services and community-led training initiatives can foster local innovation and adaptation to specific agro-climatic conditions.

Integrating traditional water harvesting methods with modern technologies offers a promising pathway to sustainability. Governments should support the restoration and maintenance of indigenous water conservation structures such as check dams and percolation tanks while encouraging technological upgrades (Bhatt et al., 2019). Policy frameworks should also emphasize inclusive and participatory water governance, promoting coordination among farmers, local authorities, and water management institutions. Such collaboration can enhance water allocation efficiency, conflict resolution, and drought preparedness (García et al., 2017).

Looking forward, advancements in artificial intelligence, remote sensing, and big data analytics hold significant potential to revolutionize drought forecasting, irrigation scheduling, and resource management. Future research should focus on developing affordable, user-friendly

technologies that are adaptable to diverse socio-economic contexts (Liakos et al., 2018). Moreover, climate change adaptation must be integrated into all water management policies, encouraging the adoption of drought-resistant crop varieties, diversification of cropping systems, and resilient farming practices to safeguard food security under changing climatic conditions (Ashraf & Foolad, 2013).Through these policy measures and innovation-driven approaches, sustainable water management in drought-prone agricultural areas can be achieved, ensuring long-term agricultural productivity and rural livelihoods.

Conclusion

Effective water management in drought-prone agricultural areas is crucial to ensuring sustainable agricultural productivity and rural livelihoods. This research highlights the importance of combining traditional water conservation practices with modern technologies such as drip irrigation, IoT-based monitoring, and data-driven decision-making tools. While these innovations offer significant potential to improve water use efficiency, challenges such as financial constraints, technical knowledge gaps, and governance issues must be addressed through inclusive policies and community engagement. Future efforts should focus on affordable technology dissemination, capacity building, and integrated water governance to build resilience against increasing drought risks exacerbated by climate change. With coordinated actions and continued innovation, water scarcity in vulnerable agricultural zones can be mitigated, contributing to food security and sustainable development.

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FARM MANAGEMENT TOOLS FOR PRODUCTIVITY: A COMPARATIVE ANALYSIS WITH LEAN TOOLS

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ABSTRACT

The growing demand for food and the pressures of climate change, resource limitations, and sustainability concerns have made the adoption of effective farm management tools essential. This paper presents a comprehensive review of various digital and traditional farm management tools and evaluates their impact on agricultural productivity. Furthermore, it compares these tools with Lean tools, originally developed for manufacturing to highlight complementarities and differences in driving efficiency, waste reduction, and continuous improvement in farming operations. The study underscores the need for integrated approaches in modern farm management for optimal productivity.

Keywords: Farm management, productivity, Lean tools, agricultural efficiency, digital agriculture, precision farming

Introduction

Agricultural productivity remains central to food security, rural development, and global sustainability. It is shaped by a complex interplay of factors, including the effective management of natural and human resources, informed decision-making, and the degree to which farms adopt innovations and technologies (FAO, 2021). As the global population continues to rise and climate change introduces new agricultural uncertainties, farmers are increasingly expected to produce more with fewer inputs. This demand has placed farm management at the core of agricultural transformation strategies (World Bank, 2023). Specifically, the use of farm management tools, ranging from traditional record-keeping methods to sophisticated digital decision-support systems; has gained momentum as a way to enhance productivity, resource optimization, and sustainability in farming systems (Klerkx & Rose, 2020; Jiménez et al., 2021).

In this evolving landscape, digital agriculture has emerged as a powerful paradigm. Technologies such as precision agriculture, remote sensing, farm management information systems (FMIS), and artificial intelligence (AI)-driven analytics are now widely recognized for their role in transforming farm operations. These tools allow farmers to monitor crop health, predict yields, track financial performance, and make real-time decisions based on accurate and timely data (Wolfert et al., 2020; Zhang et al., 2023). For example, FMIS platforms integrate agronomic, financial, and logistical data into a unified system, enabling comprehensive farm oversight and strategic planning (Goense et al., 2021). Similarly, mobile applications have enhanced access to market information, weather forecasts, and best farming practices, particularly benefiting smallholder farmers in developing regions (Misaki et al., 2022).

However, the integration of these tools into everyday farm practice is not without challenges. Factors such as digital literacy, infrastructure deficits, cost of technology adoption, and cultural resistance to change can hinder the effective utilization of advanced farm management systems (Rose et al., 2021). Consequently, achieving maximum benefit from these tools requires not only technological advancement but also the development of complementary frameworks that address human and institutional dimensions of agriculture.

Parallel to the growth of digital agriculture, the principles of Lean thinking, originally developed in the manufacturing sector, are gaining attention in agricultural discourse. Lean philosophy emphasizes the elimination of waste, continuous improvement (kaizen), and value creation from the customer's perspective (Womack & Jones, 2003). When applied to agriculture, Lean tools can streamline workflows, reduce inefficiencies in production and distribution processes, and enhance quality and consistency in farm outputs (Ruiz-de-Arbulo-Lopez et al., 2021). Tools such as value stream mapping, 5S (Sort, Set in order, Shine, Standardize, Sustain), visual management, and just-in-time (JIT) have been adapted to farming contexts with varying degrees of success (Hurst et al., 2020).

Recent studies have demonstrated the potential of Lean tools in addressing long-standing inefficiencies within agricultural value chains. For instance, a study by Alarcon and Pawlik (2022) highlighted the application of Lean principles in horticultural farms to optimize labor use, improve harvest scheduling, and reduce postharvest losses. Similarly, in livestock production, Lean tools have been employed to reduce feed waste, streamline animal movement, and improve hygiene practices, contributing to both productivity and animal welfare (Martin et al., 2021). The intersection of Lean philosophy with sustainable agriculture is particularly promising, as Lean focuses on reducing non-value-adding activities that often correlate with environmental degradation and resource inefficiency.

Nevertheless, Lean implementation in agriculture is still in its early stages and is often limited to larger commercial farms with the capacity to invest in management training and operational restructuring. There remains a gap in the literature and in practice regarding the adaptation of Lean tools for smallholder farms, which make up a significant portion of global agricultural production, especially in Africa and Asia (IFAD, 2023). Moreover, there is limited research on the synergies that may arise from combining Lean principles with digital farm management tools, which could create integrated systems for continuous improvement, data-driven decision-making, and strategic resource use. In recent years, farm management tools; both traditional and digital, have emerged as critical enablers of modern agriculture. Lean tools, derived from Lean manufacturing philosophy, also offer potential benefits when adapted to farming by eliminating waste and improving operational efficiency. This paper reviews selected farm management tools and compares them with Lean tools to identify best practices and strategic integration possibilities. Given the rapid evolution of both digital agriculture and Lean farming methodologies, there is a compelling need to compare and contrast their tools, identify best practices, and explore potential areas for strategic integration. Such comparative analysis can yield valuable insights into how different types of farm operations—ranging from small-scale subsistence farms to large commercial enterprises—can adopt appropriate management tools to enhance their productivity, sustainability, and resilience.

This paper aims to provide a comprehensive review of selected farm management tools, both traditional and digital, and assess their utility in diverse farming contexts. It also examines key Lean tools adapted from industrial practices and evaluates their relevance and impact when applied to agricultural systems. Through a comparative framework, the paper identified areas of convergence between the two approaches and highlights opportunities for hybrid models that combine the systematic rigor of Lean with the adaptability and intelligence of digital agriculture.

Furthermore, the study emphasizes the importance of contextual factors such as farm size, crop type, labor availability, market access, and regulatory environment that influence the adoption and effectiveness of management tools. In doing so, it seeks to contribute to the broader discourse on agricultural innovation and offer practical guidance to farmers, agribusinesses, extension agents, and policymakers interested in optimizing farm performance through smart and efficient management systems.

In conclusion, as the global agricultural sector confronts unprecedented challenges including climate change, supply chain disruptions, and population pressure, there is a growing recognition that productivity gains must be achieved not only through better inputs but also through smarter management. By reviewing and comparing farm management tools and Lean tools, this paper contributes to the strategic rethinking of farm operations and supports the transition toward more resilient, efficient, and sustainable agricultural systems.

Overview of Farm Management Tools

Farm management tools support farmers in planning, monitoring, analyzing, and optimizing agricultural activities. These tools can be categorized into software-based solutions, decision-support systems, and organizational frameworks. Below are five commonly used tools:

(i) **AgriWebb:** A digital farm management platform offering tools for livestock and pasture management, record keeping, and real-time analytics.

(ii) **John Deere Operations Center:** An integrated digital platform that uses machinery data to optimize field operations, input application, and yield analysis.

(iii) **Trimble Ag Software:** Provides precision agriculture solutions including crop planning, variable rate technology, and equipment guidance.

(iv) **CropX:** A soil sensing and data analytics tool that helps optimize irrigation and fertilization through real-time soil data.

(v) **FarmLogs:** A farm management software offering crop tracking, field mapping, weather insights, and input cost analysis.

Overview of Lean Tools in Agriculture

Lean tools focus on minimizing waste and improving efficiency. When applied to agriculture, they enable resource optimization and continuous improvement. Key Lean tools include:

- **5S (Sort, Set in Order, Shine, Standardize, Sustain)**
- **Kaizen (Continuous Improvement)**
- **Value Stream Mapping (VSM)**
- **Just-In-Time (JIT)**
- **Total Productive Maintenance (TPM)**

Comparative Analysis of Farm Management Tools and Lean Tools

Table 1. Key Differences between Farm Management Tools and Lean Tools

Criteria	Farm Management Tools	Lean Tools
Focus Area	Decision-making in farm operations	Process improvement and waste elimination
Industry Fit	Agriculture	Manufacturing, now extended to agriculture
Data Requirements	Agronomic, financial, environmental	Operational, procedural, performance-based
Training Needs	Agribusiness knowledge	Lean methodology and change management

Integration Pathway Flowchart

Figure 1 presents the integration pathway flowchart from traditional tools to lean-enhanced digital farm management



Figure 1 Integration pathway flowchart from traditional tools to lean-enhanced digital farm management.

Table 2. Integration Opportunities and Challenges

S/N	Opportunities	Challenges
1	Lean tools provide strategic frameworks; digital tools offer execution platforms.	Need for training and mindset shift among farmers.
2	Combined use enhances decision-making and waste reduction.	Integration may be costly and technologically demanding.
3	Automation and Lean reduce labor costs and variability in output	Data security and infrastructure remain concerns in rural areas.

Conclusion

This study has established the relationship between Lean philosophy with digital tools and sustainable agricultural productivity. Through a comparative analysis of conventional farm management tools and Lean strategies, it charts a clear course for innovation and efficiency in modern agriculture. Farm management tools and lean tools offer complementary benefits. While farm management focuses on strategic and operational decisions in agriculture, lean tools offer structured methodologies to improve efficiency. A strategic integration of both can lead to sustainable, competitive, and productive agricultural enterprises. More so, there is growing synergy in integrating lean tools into farm management systems, especially in agribusinesses and value-added processing. For instance, lean's 5S can improve farm storage and safety, and

value Stream Mapping helps streamline harvest-to-market logistics, while combining farm budgeting with Kaizen enhances financial discipline and operational efficiency.

Farm management tools have significantly transformed modern agriculture by providing actionable insights and optimizing resources. However, their full potential can be unlocked when strategically combined with Lean tools, fostering a culture of continuous improvement and systematic efficiency. Future strategies should focus on hybrid models integrating Lean philosophy with digital tools to ensure sustainable agricultural productivity.

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NETWORKING WITH PURPOSE: HOW TO BUILD RELATIONSHIPS THAT CONNECT AND PROPEL

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ABSTRACT

Networking, often associated with exchanging professional contacts, goes beyond the mere exchange of information. This paper explores the importance of an authentic, intentional, and consistent approach to building meaningful and lasting professional relationships. The research highlights how networking, when practiced with purpose, can foster personal and professional growth, driven by a strong personal brand and mutual value creation. It also discusses the importance of reciprocity in interactions, emphasizing the quality over the quantity of connections. Through the analysis of effective strategies for cultivating these relationships, this study concludes that networking should be viewed not only as a tool for immediate success but as a means to strengthen collaboration and foster long-term opportunities.

1. Introduction

In today's world, professional connections play a crucial role in career development and personal growth. The concept of networking, often confused with simple contact exchanges or self-promotion, has evolved into a deeper process of building genuine and collaborative relationships. This paper discusses how networking can be practiced authentically and intentionally to create meaningful relationships that drive the development of both parties involved.

Networking with purpose involves the exchange of value, where connections are not just means to achieve individual goals, but opportunities to contribute to the growth of others. Through the analysis of various aspects, such as personal branding and reciprocity in interactions, we will discuss how to build a solid network focused on quality, trust, and collaboration.

2. Literature Review

The literature on professional networking is extensive and varied, ranging from traditional contact strategies to the latest digital trends. According to Cross, Thomas, and McArthur (2016), networking is seen as a strategic practice that not only increases professional visibility but also facilitates access to valuable information and resources. However, many authors argue that traditional networking approaches are insufficient to build lasting relationships.

In their research, Ibarra (2003) suggests that effective networking should be based on a relational approach, where trust-building and mutual value are key. For Grant (2017), intentional networking, which prioritizes reciprocity and collaboration, has the potential to transform a network of contacts into a supportive professional community. Additionally, studies on authenticity, such as those by Goffee and Jones (2000), emphasize the importance of building a strong personal brand that reflects genuine values, making it easier to form more meaningful connections.

3. Methodology

The research was conducted through a qualitative and exploratory analysis, reviewing academic studies on the impact of authentic approaches to networking, as well as conducting interviews with professionals from various fields. Data collection included semi-structured interviews with industry leaders, focusing on the strategies and experiences they find most effective in building lasting and collaborative relationships. Moreover, case studies of companies and professionals who have succeeded in purposeful networking practices were also analyzed.

4. Results

The research findings indicate that professionals who adopt an authentic and intentional approach to networking build more lasting and valuable relationships. The development of a strong personal brand was identified as an essential factor for the success of these interactions. Additionally, the most effective relationships are those in which both parties share value, with a clear balance between giving and receiving.

The research also revealed that, contrary to popular belief, the volume of connections is not an indicator of success in networking. Professionals who focused on the depth and quality of interactions demonstrated higher satisfaction and better long-term results. Consistency in

interactions, such as following up with thank-you messages or sharing relevant resources, was highlighted as a key strategy to keep these relationships active.

5. Discussion

Building an effective network is not a matter of numbers, but of genuine value. Through an approach grounded in authenticity, professionals can create a network that goes beyond superficial connections. The strongest relationships are those where there is a true interest in contributing to the success of the other, establishing a foundation of trust and mutual respect.

Furthermore, the importance of personal branding in the networking process cannot be underestimated. In an increasingly digital world, first impressions are often made online. Having clarity about who we are and what we represent allows us to become more memorable and, thus, strengthen relationships over time.

Reciprocity, in turn, is key to maintaining these relationships and ensuring that networking is a two-way street. When interactions are balanced, connections turn into genuine collaborations and opportunities that benefit all involved.

6. Conclusion

True success in networking lies not only in the opportunities it brings but in the quality of the relationships built over time. When practiced with authenticity, purpose, and consistency, networking becomes a powerful tool for professional and personal growth. By focusing on creating value, building trust, and cultivating a strong personal brand, we can transform networking from a superficial practice into a path of collaboration and mutual growth. The connections built in this way not only propel our careers but also have the potential to make a meaningful impact on the lives of all involved.

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ANALYSIS OF GEOPOLYMER CONCRETE'S COMPRESSIVE STRENGTH PARAMETRICALLY

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ABSTRACT

Concrete is becoming more and more in demand every day to meet the demands of infrastructure development. It is commonly known that producing OPC releases a sizable amount of carbon dioxide into the environment in addition to consuming a large amount of energy and natural resources. Finding alternatives is therefore crucial to making concrete environmentally friendly. Fly ash is used to create the inorganic alumino-silicate substance known as geopolymer. Although fly ash, one of the raw materials for geopolymer binders, is widely available in India, its use is still somewhat restricted. Therefore, in order to make concrete more environmentally friendly, efforts must be made to use this by-product in the production process. In order to improve its overall performance, this study details the experimental work done by casting 20 geopolymer concrete mixes to assess the impact of different factors impacting its compressive strength. Numerous factors have been examined, including the proportion of fly ash to alkaline liquid, the concentration of sodium hydroxide, the proportion of sodium silicate to sodium hydroxide, the curing temperature and duration, the dose of superplasticizer, the rest period, and the extra water content in the mixture. According to the test results, compressive strength rises as curing time, temperature, rest period, and sodium hydroxide solution concentration increase, whereas it falls as the mass ratio of water to geopolymer particles and admixture dose increase. The workability of geopolymer concrete is enhanced by the use of a superplasticizer based on naphthalene. It was also noted that attaining the required compressive strength in geopolymer concrete is significantly influenced by the water content of the mixture.

Keywords: Geopolymer, Concrete, Fly ash, Compressive strength, Parametric study.

1.Introduction:

One of the materials that is utilized extensively worldwide is concrete. The main binder used to make the concrete is ordinary Portland cement (OPC). Due to the necessity of developing infrastructural facilities, the demand for concrete is growing daily .However, it is widely known that producing OPC emits a sizable amount of carbon dioxide into the environment in addition to using a large amount of energy and natural resources . The global cement industry contributes around 2.8 billion tons of the greenhouse gas emissions annually, or about 7% of the total manmade greenhouse gas emissions to the earth's atmosphere. It is essential to find alternatives to make environment friendly concrete. One of the alternatives to produce more environmentally friendly concrete is to replace the amount of Portland cement in concrete with by-product materials such as fly ash. An important investigation in this regard is the development of high volume fly ash concrete that utilizes up to 60 percent of fly ash, and yet possesses excellent mechanical properties with enhanced durability performance. Another alternative to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, called Geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that is rich in silicon and aluminum [4]. Fly ash, one of the source materials for geopolymer binders, is available abundantly worldwide, but to date its utilization is limited. Currently, 90million tones of fly ash is being generated annually in India. By exploring use of the fly ash based geopolymer concrete two environment related issues are tackled simultaneously i.e. the high amount of CO_2 released to the atmosphere during production of OPC and Utilization of this fly ash.

The production of geopolymer concrete is carried out using the conventional concrete technology methods. The fly ash based geopolymer concrete consists 75% to 80% by mass of aggregate, which is bound by age polymer paste formed by the reaction of the silicon and aluminum within the fly ash and the alkaline liquid made up of sodium hydroxide and sodium silicate solution with addition of superplasticiser. In this paper,various factors which influencing the strength of concrete are studied and results are discussed by various graphs corresponding to the strength of the test cubes.

It can be observed from the above discussion that the geopolymer concrete has not been studied much in detail in India. India also is facing the problem of depletion on natural resources such as lime stone which is the most important ingredient to produce cement and in turn the concrete in India. In this situation, detailed study of geopolymer concrete which is the concrete with zero cement in concrete naturally becomes very important. Therefore, an attempt has been made in the present investigation by casting 20 geopolymer concrete mixes with 100% replacement of OPC with processed fly ash in each concrete mix [5]. Indian standards have always emphasized on the importance of compressive strength amongst various mechanical properties of concrete. Hence, the effect of various parameters affecting the compressive strength i.e.ratio. alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, dosage of superplasticiser, rest period and additional water content in the Geopolymer concrete mixes has been investigated in order to enhance its overall performance.

1.Experimental Programme

Materials

Fly ash used in this study was low calcium class F processed fly ash from Dirk India private limited under the name of the product POZZOCRETE60. Chemical compositions of the fly ash used along with the specifications are given in Table 1.

Table 1. Composition of class F fly ash (POZZOCRETE)

SiO2	Al2O3	Fe2O3	MgO	SO3	Na2O	CaO	LOI
57.30%	27.13%	8.06%	2.13%	1.06%	0.73%	0.03%	1.60%

The alkaline liquid used was a combination of sodium hydroxide and sodium silicate solution. Sodium hydroxide (NaOH) in flakes form with 98% purity purchased from local chemical supplier was used and Sodium silicate solution (Na_2O = 16.84%, SiO_2= 35.01% and water = 46.37% by mass) was used as alkaline liquid. Sodium hydroxide solution is prepared by dissolving the flakes in water. Tap water available in laboratory was used to prepare NaOH solution. The activator solution was prepared at least one day priortoits use. Locally available 10 mm and 20mm crushed aggregates have been used as coarse aggregates. Locally available rivers and isused as fine aggregate in the concrete mixes. To improve the workability of the fresh geopolymer concrete, naphthalene sulphonate based superplasticizer was used in all of the geopolymer mixes.

Casting of concrete mixes

The mixing procedure used for geopolymer concrete is similar to that of conventional OPC concrete. Mixing of all the materials have been done in the laboratory at room temperature. The fly ash and the aggregate were mixed together in concrete pan mixture. The mixing is allowed to continue for about 3 to 4 minutes. The alkaline solution which was prepared one day before is added with additional water in the mix. The liquid component and superplasticiser was added to the dry material and mixing is continued for another 3 to 4 minutes.

Thefreshconcreteiscastintothemouldsimmediatelyaftermixingintwolayersforprismaticspecimens.For compaction of the concrete specimens, each layer was given 25 to 35 manual strokes using 20 mm rod. Concrete specimens were vibrated using vibration table for another 10 to 15 seconds. After the casting, the concrete specimen was kept at room temperature as per the decided rest period.

The details of mix design for geopolymer concrete Mix-1 to Mix-6 is given in Table 2. The coarse and fine aggregate proportions used in different geopolymer concrete mixes are about 75-77 % percent by mass of the concrete.

Table2. Ingredients for geopolymer concrete Mix-1 to Mix-6

Ingredient	Unit	Mix-1	Mix-2	Mix-3	Mix-4A	Mix-4B	Mix-5A	Mix-5B	Mix-5C	Mix-6A	Mix-6B
Fly ash	kg/m^3	428	444	428	428	428	428	428	428	428	428
C.A	kg/m^3	1170	1170	1170	1170	1170	1170	1170	1170	1170	1170
F.A	kg/m^3	630	630	630	630	630	630	630	630	630	630
Na2SiO3	kg/m^3	122	111	114	122	122	122	122	122	122	122
NaOH	kg/m^3	49	44	57	49	49	49	49	49	49	49
Extra water	kg/m^3	43	43	43	43	43	43	43	43	43	43
Molarity		14	14	14	14	14	14	14	14	14	14
Superplasticiser	kg/m^3	8.5	9	8.5	8.5	8.5	8.5	13	17	8.5	8.5
Curing temp	^0C	75	75	75	75	75	75	75	75	75	
Curing period	Hours	24	24	24	24	48	48	48	48	48	48
Rest period	Days	1	1	1	0	0	0	0	0	0	1
No. of cube		3	3	3	3	3	3	3	3	3	3

Curing of concrete specimen

The concrete specimens were heat cured in oven at required temperature up to the completion of curing time. After the curing period,the test specimens left in the moulds for at least 4-6 hours in order to avoid a major change in the environmental conditions. After demoulding, the concrete specimens are allowed to become air-dry in the laboratory until the day of the testing

2.Results and discussion

Ratio of alkaline liquid to fly ash

Two concrete mixes Mix-1 and Mix-2 with the alkaline liquid to fly ash ratio 0.35 and 0.4 have been cast using the ingredients as given in Table 2. The effect of alkaline liquid to fly ash ratio by masson compressive strength of concrete at age 3 days has been evaluated by comparing results of both mixes. The results are presented in Fig. 1. It has been observed that the ratio of alkaline liquid to fly ash, by mass, is not much effective in varying the compressive strength of the geopolymer concrete.

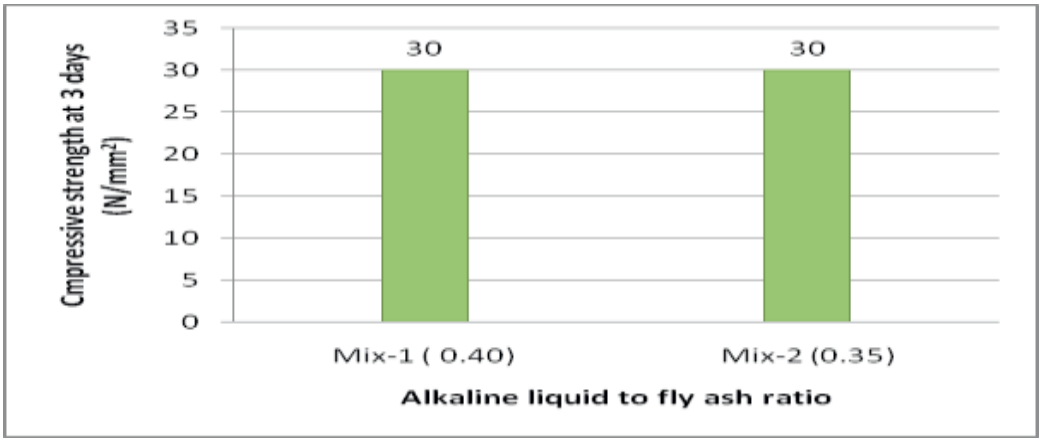
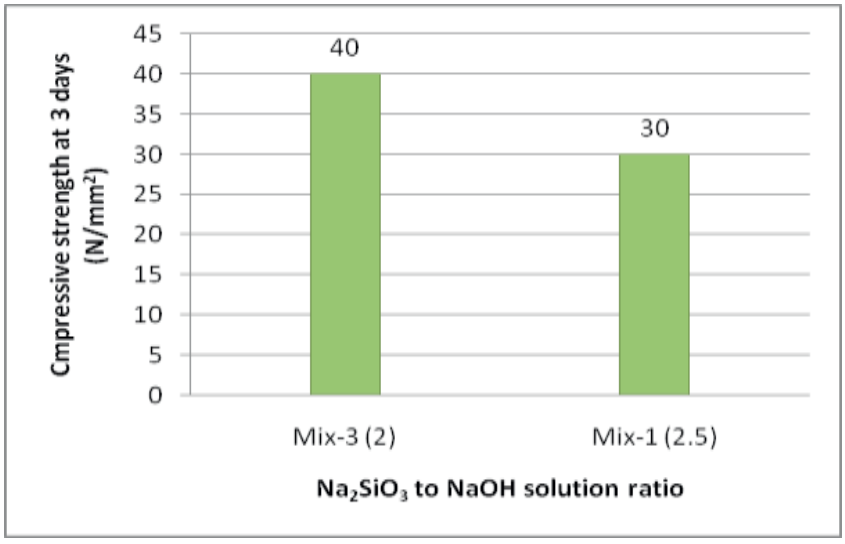


Fig.1 Effect of alkaline liquid to fly ash ratio on compressive strength

Ratio of sodium silicate solution to sodium hydroxide solution

The effect of sodium silicate solution to sodium hydroxide solution by masson compressive



strength of concrete has been observed by comparing results of Mix and Mix having ingredients as given in Table 2. The results are presented in Fig 2 Higher Compressive strength has been observed in concrete Mixs compared to that of concrete Mix.

Curing time

In order to investigate the effect of curing time, test specimens have been cured for curing periods of 24 hours and 48hours, respectively. Concrete Mix 4 with ingredients used as per Table 2 has been cast for investigating of the influence of curing time on the compressive strength.

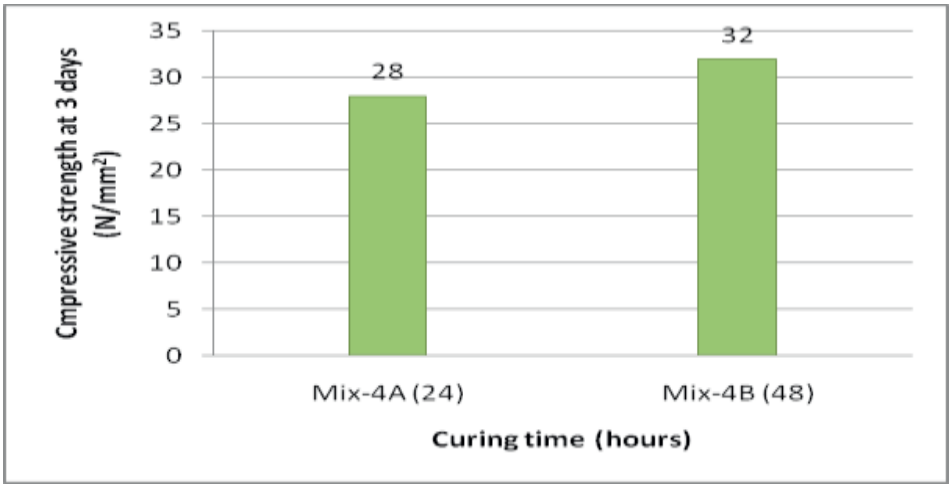


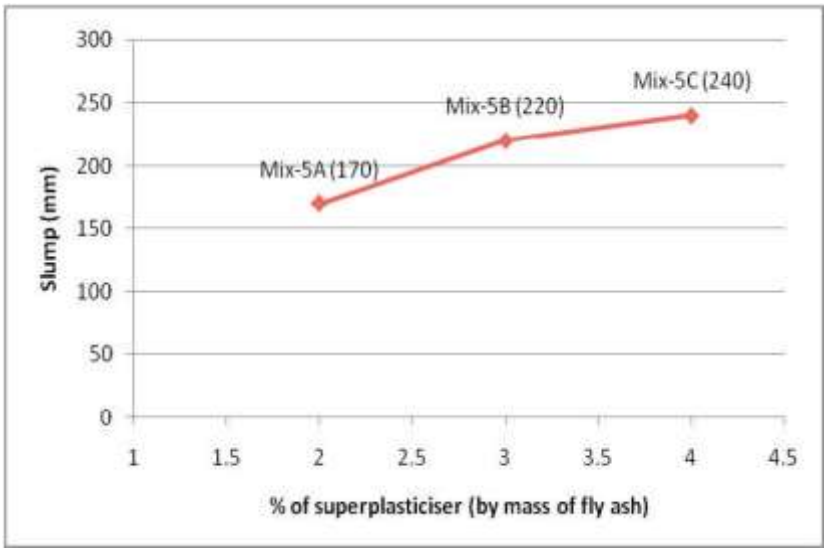
Fig.3.Effect of curing time on compressive strength

Fig shows that Longer curing time has improved the polymerisation process resulting in development of higher compressive strength. Rapid rate of increase in the strength has been observed up to the curing time of 24 hours.

Additional of superplasticiser

Geopolymer concrete has a stiff consistency in the fresh state. Although adequate compaction was achievable, an improvement in the workability was considered as desirable. Superplasticiser has been added in proportion to the fly ash in the concrete mix by mass as given in Table 2. Tests have been performed to study the effect of adding conventional commercially available Naphthalene Sulphonate based super plasticiser.

The test specimens have been cured for 48 hours at 75^0C in an oven. The effect of addition of superplasticiser on compressive strength of concrete has been observed by comparing results of Mix as presented in Table2 Concrete mixes have been cast using 2%, 3% and 4% dosage of admixture, respectively.



Concentration of sodium hydroxide solution

Mix has been cast using ingredients as shown in Table 3 to study the effect of concentration of sodium hydroxide solution on the compressive strength of geopolymer concrete. The measured compressive strength of test specimens after 7 days is given in Fig9

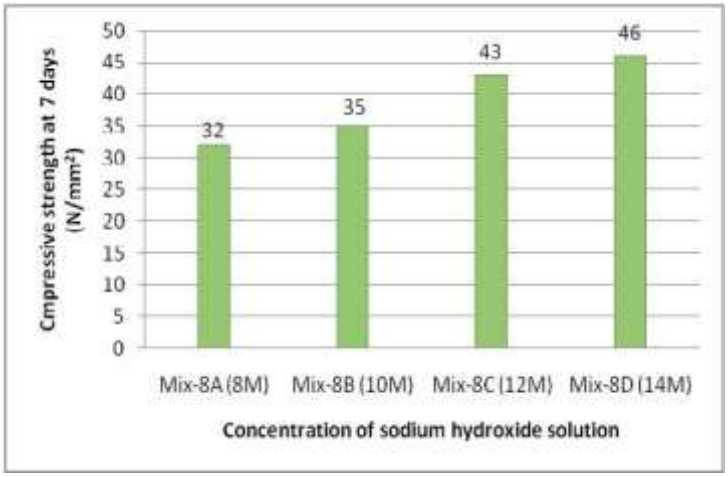


Fig.9. Effect of concentration of sodium hydroxide solution on compressive strength

The difference between a of Mix in terms of variation in compressive strength is the molar concentration of sodium hydroxide solution. Mix D with 4M concentration of sodium hydroxide solution has been able to gain much higher compressive strength as compared to other cases. It has been observed that, higher concentration of sodium hydroxide solution gives better results in terms of compressive strength of geopolymer concrete

4. Conclusions

Following concluding remarks have been made on basis of the work conducted:

- The ratio of alkaline liquid to fly ash, by mass does not affect the compressive strength of the geopolymer crea
- The sodium silicate to sodium hydroxide ratio by mass equal to 2 has resulted into the higher compressive strength a compared to the ratio of 2.5 for the geopolymer concrete.
- The compressive strength of the geopolymer concrete increases with increa of concentration in terms of molarities of sodium hydroxide.
- The compressive strength of the geopolymer concrete increases with increase in the curing time. However, the increase in strength beyond 24 hours is not much significant.
- Workability of the geopolymer concrete mix increase with the addition of superplasticiser up to 4% of fly ash by mass. Minor reduction of compressive strength of the geopolymer concrete is observed when the superplasticizer dosage used is greater than 2%.
- 1 day rest period in rathe compressive strength of the geopolymer concreteas compared to that for the concrete without the rest period.
- Compressive strength of the geopolymer concrete decreases with increase in the ratio of water to geopolymer solids by a

- The workability of the geopolymer concrete in fresh state increases with the increase of extra water added to the mix.
- Within crease in the curing temperature in the range of 60 ^{0}C to 90 ^{0}C the compressive strength of the geopolymer concrete also increases

It has been observed from the above discussion that wide variety of parameters affect the compressive strength of the geopolymer concrete. Therefore, parametric study of various factors affecting the compressive strength of the geopolymer concrete is strongly mended first before conducting any further investigations related to mechanical properties and durability of the geopolymer concrete in order to get the desirable benefits from the further investigations.

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T.C.
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