

1. Uluslararası KÜLTEPE

Bilimsel Araştırmalar ve İnovasyon Kongresi

23-24 MART 2026
KAYSERİ



EDİTÖRLER:

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DOÇ.DR. ÖZLEM ÜLGER DANACI
Dr.Onur BİLGİN



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CONGRESS ID

CONGRESS TITLE

1. INTERNATIONAL KÜLTEPE SCIENTIFIC RESEARCH AND INNOVATION CONGRESS

DATE AND PLACE

23-24 MARCH 2026 KAYSERİ/ TÜRKİYE ONLINE PRESENTATIONS

ORGANIZATION

ISARC Academy INTERNATIONAL SCIENCE AND ART RESEARCH CENTER

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Scientific Development and Innovative Approach

1th INTERNATIONAL KÜLTEPE SCIENTIFIC RESEARCH AND INNOVATION CONGRESS 23-24 MARCH KAYSERİ

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ZOOM

MEETING ID: 847 4217 4227

PASSCODE: 074224

<https://us06web.zoom.us/j/84742174227?pwd=IGrB2cGkSop256oPIAwdPaZaYrY4Tb.1>





23.03.2026 / Hall-1, Session-1



ANKARA LOCAL TIME



10⁰⁰ : 11⁴⁵



MEETING ID: 847 4217 4227



PASSCODE: 074224

HEAD OF SESSION: *Prof. Dr.Halil Barış ÖZEL*

TOPIC TITLE	AUTHORS	AFFILIATION
Effects Of Some Effective Microorganisms (EM-1 AND EM-5) On Germination Parameters Of Oriental Hornbeam (<i>Carpinus orientalis</i> Mill.) Seeds	Kadir Can GÜLEÇ Prof. Dr.Halil Barış ÖZEL	Bartın University
The Effect Of Fe ₂ O ₃ Nanoparticles On Some Physiological Characteristics Of Silver Linden (<i>Tilia tomentosa</i> Moench.) Seedlings	Prof. Dr.Halil Barış ÖZEL Burak GÜL	Bartın University
Digital Agriculture And Rural Development: A Comparative Assessment Of Turkey In The Context Of Sustainability, The Digital Divide, And Green Transformation	Dr. Kübra ASLAN YILMAZ	Ankara University
Flow Past A Submerged Vane	Dr.Firat GUMGUM	Dicle University
Thermal And Electrical Performance Evaluation Of Lead-Free Ag-Sb Solder Alloy System	Esra ÖZTÜRK	Kocaeli University
Improvement Of The Photocatalytic Properties Of Titanium Dioxide (TiO ₂) Nanomaterials On Fuchsin Dye	Assist. Prof. Dr.Nazmi SEDEFOĞLU Hilal ÖDAŞ Zeliha DAĞ	Osmaniye Korkut Ata University
An Analysis Of The Number Sense Components Of The Turkey Century Education Model Mathematics Curriculum	Prof. Dr. Cemalettin IŞIK Kiraz KOÇ ŞANLI	Erciyes University/ Ministry of National Education, Kanuni Sultan Süleyman Secondary School





23.03.2026 / Hall-2, Session-1



ANKARA LOCAL TIME



10⁰⁰ : 11¹⁵



MEETING ID: 847 4217 4227



PASSCODE: 074224

HEAD OF SESSION: *Assist. Prof. Dr. Onur BİLGİN*

TOPIC TITLE	AUTHORS	AFFILIATION
Alexithymia In Individuals With Epilepsy	Nuray BİNGÖL Res. Assist. Neşe AYKUT	Atatürk University/Ağrı İbrahim Çeçen University
Current Approaches To Dietary Therapy In Epilepsy: The Ketogenic Diet	Nuray BİNGÖL Res. Assist. Neşe AYKUT	Atatürk University/Ağrı İbrahim Çeçen University
Service Quality And Patient Satisfaction In Emergency Healthcare: A Conceptual Review	Pınar KURAL Tuğba ŞAHİN ÇİÇEK	Istanbul Aydın University
The Role Of The Free Trade Agreement In Enhancing Trade Relations Between Türkiye And Malasia	Latife YAŞAR Assist. Prof. Dr. Onur BİLGİN	Kırıkkale University
Erasing The Other In Digital Culture: The Proliferation Of The Sameness And The Loss Of Negativity	Prof. Dr. İhsan ÇAPCIOĞLU Ayça YILDIRIM	Ankara University





23.03.2026 / Hall-3, Session-2



ANKARA LOCAL TIME

10³⁰ : 12⁰⁰



MEETING ID: 847 4217 4227

PASSCODE: 074224

HEAD OF SESSION: *Assist. Prof. Dr. MUHAMMAD FAISAL*

TOPIC TITLE	AUTHORS	AFFILIATION
The Economic, Legal And Social Effects Of The Oligopolistic Structure In The Mobile Telephony Market In Albania	Phd. Ansi Kotollaku MSc Ylgersa Cara Prof.As.Mimoza Kotollaku	Universiteti i Elbasanit/ALBANIA
Managing Aquifers 'Mitigating Climate Change: Building The Case For Quetta City Towards Future Sustainable Water Management	Ar. Fahad Khan Dr. Ar. Omer Shujat Bhatti	School of Architecture & Planning, University of Management & Technology/PAKISTAN
Some Identities In Left Near-Rings With P-Derivations	Abdelkarim BOUA	Sidi Mohammed Ben Abdellah University/MOROCCO
Mahatma Gandhi And Dr. B.R. Ambedkar : Contesting Views On Social Justice And Dalit Emancipation	SIDDHI BHARTI	UNIVERSITY OF DELHI/INDIA
Improving Nitrogen Use Efficiency For Environmental Protection	ELABBARI Chaimaa , Pr. Labjar Najoua , Elouali Ouïjdane , EL BOUZIDI Ahmed ,ZINA OUI Badre , Pr.EL Hajjaji Souad	Mohammed V University in Rabat
AI Governance Frameworks for Digital Transformation	Assist. Prof. Dr. MUHAMMAD FAISAL	Allama Iqbal Open University/INDONESIA



23.03.2026 / Hall-4, Session-2



ANKARA LOCAL TIME

10³⁰ : 12¹⁵



MEETING ID: 847 4217 4227

PASSCODE: 074224

HEAD OF SESSION: *Dr. S. Selvam*

TOPIC TITLE	AUTHORS	AFFILIATION
Harnessing Saharan Actinomycetes for Innovative and Sustainable Phytopathogen Control	Fedwa BEGHDAI El-Hadj DRICHE	Hassiba Benbouali University of Chlef/ALGERIA
Adaptation-Driven Antifungal Activity of Actinobacteria from Tamanrasset Desert Soils	Fedwa BEGHDAI El-Hadj DRICHE	Hassiba Benbouali University of Chlef/ALGERIA
Saharan Microbial Resources as a Sustainable Strategy for Crop Disease Management	Fedwa BEGHDAI El-Hadj DRICHE	Hassiba Benbouali University of Chlef/ALGERIA
Biocontrol Potential of Saharan Actinomycetes Isolated from Tamanrasset Arid Soils	Fedwa BEGHDAI El-Hadj DRICHE	Hassiba Benbouali University of Chlef/ALGERIA
Relationship Between Foot Pain and Different Shoe Base Area	Seifleslasie Asmamaw Tamrat Tesfaye Biniyam Solomon	Bahir Dar University/ETHIOPIA
Digital Forensics in Cybercrime Investigation	S. Reashmi Dr. S. Selvam	Nadar Mahajana Sangam S. Vellaichamy Nadar College/Kamaraj College of Engineering and Technology
Integrating Case Studies In English Language Teaching: Developing Intercultural Competence In Higher Education	Olivera PRESI	“Aleksandër Moisiu” University/ALBANIA



23.03.2026 / Hall-5, Session-2



ANKARA LOCAL TIME

10³⁰ : 11⁴⁵



MEETING ID: 847 4217 4227



PASSCODE: 074224

HEAD OF SESSION: *Dr.Nodar Sulashvili*

TOPIC TITLE	AUTHORS	AFFILIATION
On Paired Kannan-Type Contractions Via Paired Contractions In Partial Metric Spaces	Rhoda Chiroma, Mohammed Shehu Shagari	Federal University/Ahmadu Bello University
Real-Time Fault Monitoring By Sensor-Based Machine Learning (MI) With Electromagnetic (Em) Field Energy Harvesting	Duvvuru Hasini , M.Jahnavi , Badi Bhruthi , Choppa Jyoshna , Akshaya .V , Dr. G. Nixon Samuel Vijayakumar	R.M.K. Engineering College
Advanced Pharmacological Perspectives On Antiarrhythmic Drug Therapy: Ion Channel Modulation, Pharmacokinetic Variability, Metabolic Regulation, Therapeutic Monitoring, And Clinical Safety Considerations	Dr.Nodar Sulashvili , Ia Egnatievi , Ada (Adel) Tadevosyan , Vira Kravchenko , Olga Shapoval , Marika Sulashvili , Igor Seniuk 7, Tamar Okropiridze	Alte University/Sulkhan-Saba Orbeliani University/Yerevan State Medical University/National University of Pharmacy/Kharkiv State Medical University/Health Sciences at The University/GEORGIA/USA/UKRAINE
Extensively Disseminated Luminal B Metastatic Breast Carcinoma With Widespread Visceral, Skeletal And Cns Metastases: Diagnostic Complexity, Multimodal Imaging Correlation, Therapeutic Implications Of Cdk4/6-Based Endocrine Targeting And Pharmacotherapy Strategies (Case Study)	D.Nodar Sulashvili Lali Patsia Ada (Adel) Tadevosyan Vira Kravchenko Olga Shapoval Marika Sulashvili Igor Seniuk Tamar Okropiridze	Alte University/Sulkhan-Saba Orbeliani University/Yerevan State Medical University/National University of Pharmacy/Kharkiv State Medical University/Health Sciences at The University/GEORGIA/USA/UKRAINE
Patients' Satisfaction With Water Supply And Sanitation In The Primary Healthcare Centres Of Ibadan South East Local Government Area	S. A. Adejumo U.U. Jimoh Busayo T. Ojetunji	University of Ibadan



23.03.2026 / Hall-6, Session-2



ANKARA LOCAL TIME

10³⁰ : 12⁰⁰



MEETING ID: 847 4217 4227



PASSCODE: 074224

HEAD OF SESSION: *Dr. Duong To Quoc THAI*

TOPIC TITLE	AUTHORS	AFFILIATION
Developing Historical Competencies For High School Students Through Project-Based Learning: A Case Study Of The Industrial Revolutions Topic In Vietnam	M.A. Tran Thi HIEN Nguyen Thi Phuong HUYNH Nguyen Thi Thu GIAU Duong To Quoc THAI	Dong Thap University, VIETNAM
Toward Efficient Energy Management Of Isolated Hybrid Microgrids Integrating Photovoltaic Generation, Battery Storage And Diesel Generators	Narjisse Douiri Mohammed Kissaoui Lhoussaine Bahatti	Hassan II University
Transformations In The Agricultural Economy Of The Plain Of Reeds From 1867 To 1945	Dr. Duong To Quoc THAI M.A. Dương Văn Triêm Nguyen Thi Vu Lan	Dong Thap University, VIETNAM
Sustainable Approach To Water Scarcity In Arid Areas By Using Renewable Energy For Desalination	Chaimae Lamiri, Jamal Mabrouki , Khadija El-Moustaqim Younes Abrouki	Mohammed V University/Ibn Tofail University/MOROCCO
Utilization Of Open Educational Resources (Oer) In The Teaching Of English Language Grammar In Senior Secondary Schools In South East Nigeria	Chekwube Chiebonam Mbegbu PhD Annah Chinyeaka Uloh-Bethels PhD Ngozi Nkechi Okonji PhD	University of Nigeria
Power And Maritime Border Transformations: Examining The Role Of Iranian Governance In The Persian Gulf During The Qajar Period	Mohammad Reza Alam Seyyedeh Niloofar Bakhoda	Shahid Chamran University/IRAN



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ISARC academy MELIKE KAYA OJETUNDE BUSAYO T.

The screenshot shows a PowerPoint presentation in Protected View. The slide is titled "Contents" and lists the following topics:

- Introduction
- Literature Review
- Study Area
- Methodology
- Findings and Discussion

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- Prof. Dr. Halil Barış Özel
- H-1 S-1 KIRAZ KOÇ ŞANLI
- Hall 1-Esra Öztürk
- Hall 1-Nazmi Sedefoğlu
- Hall 1-Prof.Dr.Halil Barış ÖZEL

The screenshot shows a PowerPoint presentation in the "MATERIAL AND METHOD" section. The slide content is as follows:

MATERIAL AND METHOD

The material of the research consists of oriental beech seeds collected from silver linden seed stands in the Zonguldak-Tefen region in 2022. The seeds collected in September were cleaned and immediately transported to the laboratory in sterile bags without losing their moisture content and were subjected to the necessary pre-treatments to eliminate their germination barriers. The seeds were stored at +4 degrees and 70% humidity.

Sterile seeds were subjected to vitality checks by cutting and floating experiments. Healthy seeds that successfully passed the vitality test were separated from the others and after these processes, the obtained beech seeds were subjected to cold stratification for 6 weeks at 3°C and 30% humidity. The seed is kept at a value between the minimum humidity level required for breaking dormancy and the humidity it has in a fully saturated state. When the seed is cold-treated at this humidity level of +3±2 °C, dormancy is broken but germination does not occur. Then, the moisture content is determined according to the fresh weight to determine the target moisture content of the seeds to be stratified. The seeds with adjusted moisture were kept at the same humidity or in the moisture content range where stratification occurs without germination throughout stratification. The seeds that were worked on are cold-treated in partially ventilated containers or nylon bags.

4 atanmamış katılımcı



DigitalAgriculture_KubraAslanYilmaz - PowerPoint

Oturum açın

Dosya Giriş Ekle Çiz Tasarım Geçişler Animasyonlar Slayt Gösterisi Kaydet Gözden Geçir Görünüm Yardım Acrobat Ne yapmak istediğinizi söyleyin Paylaş

Yapıştır Yeni Slayt Bölüm Pano Slaytlar Yazı Tipi Paragraf Şekiller Yerleştir Hızlı Stiller Çizim Şekil Dolgusu Şekil Ana Hattı Şekil Efektleri Bul Değiştir Seç PDF oluşturma Adobe Acrobat Eklenir Eklenir

INTRODUCTION 01

Structural Pressures

Climate change, food insecurity, labour outmigration, depleting natural resources - compounding simultaneous challenges for rural communities.

Agriculture 4.0

AI, IoT, big data analytics, UAVs and precision farming emerge as both a promising solution and a potential new source of inequality.

SDG Linkages

SDG 2 (Zero Hunger) - SDG 8 (Decent Work) - SDG 10 (Reduced Inequalities) - SDG 13 (Climate Action)

Central question: Can digital agriculture deliver inclusive rural transformation - or will it deepen existing inequalities?

Dr. Kübra ASLAN YILMAZ | Ankara University, Department of Agricultural Economics



FLOW PAST A SUBMERGED VANE

- Submerged vanes are hydraulic structures that protruding from the bed and creating a pressure difference between their two faces [1].
- This pressure difference, similar to that of an airplane wing (Figure 1a), creates a tip vortex that significantly modifies the flow field downstream (Figure 1b).

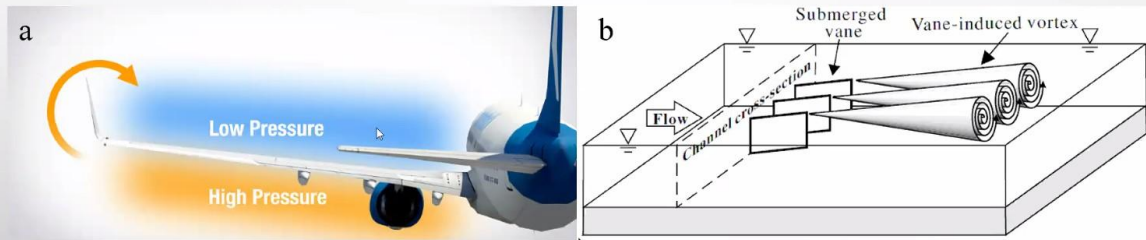
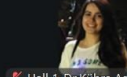
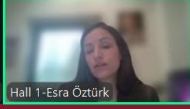


Fig. 1 – a) Tip vortex induced by an airplane wing [2], b) Tip vortices induced by a submerged vane-array [3].



Lead and lead compounds were introduced as one of **17** toxic chemicals that are harmful and dangerous to the human life and environment by EPA (Environmental Protection Agency).

When lead interacts with the human body, it changes the normal functioning of proteins. Lead dust and vapor generated during soldering, can cause irreversible health problems, such as neurological disorders, reproductive problems, high blood pressure, decreased hemoglobin production, vasoconstriction, anemia, etc. In addition, disposal of lead in the environment has been considered very detrimental.

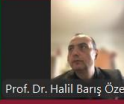
Among Pb-free alternatives, Silver (Ag) is widely used in solder alloys because of its excellent electrical and thermal conductivity as well as its good wetting characteristics, which are essential for reliable electronic interconnections. Antimony (Sb), is known to enhance mechanical strength, creep resistance, and thermal stability in metallic alloys. The combination of Ag and Sb can lead to the formation of intermetallic phases that significantly influence the microstructure and transport properties of the alloy system. Therefore, Ag-Sb alloys are considered promising candidates for the development of environmentally friendly Pb-free solder materials with improved mechanical and thermal performance.



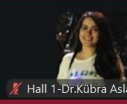
TiO₂

- Titanyum dioksit (**TiO₂**, geniş bant aralığı(3.2eV) ve elektronik malzemeler, paketlenme, yiyecek endüstrisi ve kozmetik ürünler başta olmak üzere yaygın kullanıma alanına sahip bir yarıiletken'dir.
- Titanyum dioksit (TiO₂), büyük fotokatalitik aktivitesi, kimyasal ve biyolojik kararlılığı, suda, asit ve baz ortamında çözünmezliği, korozyona karşı direnci, toksik olmaması, düşük fiyatı ve oksit, sülfür ve diğer malzemelere kıyasla bulunabilirliği nedeniyle yaygın olarak kullanılan en öne çıkan fotokatalizördür

ISARC academy...



Hall 1-Nazmi Se...



Hall 1-Esra Öztürk



ISARC academy MELİKE KAYA

H-1 S-1 KIRAZ KOÇ ŞANLI

Prof. Dr. Halil Barış Özel

Hall 1-Nazmi Sedefoğlu

Hall 1-Dr.Kübra Aslan Yılmaz

Hall 1-Esra Öztürk

KÜLTEPE KONGRE SUNU - PowerPoint (Ürün Etkinleştirilmedi)

kriraz koç

Dosya Giriş Ekle Tasarım Geçişler Animasyonlar Slayt Gösterisi Kaydet Gözden Geçir Görünüm Yardım Acrobat Ne yapmak istediğinizi söyleyin Paylaş

Yapıştır Yeni Slayt Bölüm Slaytlar Yazı Tipi Paragraf Çizim Yerleştir Hızlı Stiller Şekil Efektleri Şekil Doldusu Şekil Anahattı Şekil Efektleri Bul Değiştir Seç PDF oluşturma Ekleniler

1 KÜLTEPE

2

3 SAYI HISSİ

4

5

6

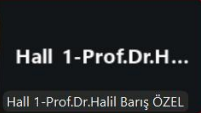
SAYI HISSİ

Alanyazında sayı hissine yönelik farklı tanımların bulunduğu görülmektedir.

Hope (1989), sayı hissini sayısal durumlara ilişkin mantıklı tahminlerde bulunabilme ve uygun hesaplama yollarını seçebilme yeteneği olarak

Howden (1989), sayılar ve aralarındaki ilişkiler hakkında sezgisel bir anlayış geliştirme becerisi olarak

Berch'e (2005) göre ise sayı hissi, bireyin sayıların anlamına ilişkin geliştirdiği duyuşal farkındalık olarak tanımlanmaktadır.



H-1 S-1 KIRAZ KOÇ ŞANLI

Prof. Dr. Halil Barış Özel

Hall 1-Nazmi Sedefoğlu

Hall 1-Esra Öztürk

Hall 1-Dr.Kübra Aslan Yılmaz

Hall 1-Prof.Dr.Halil Barış ÖZEL

ETKİLİ MİKROORGANİZMA SUNUMU - PowerPoint

Oturum Aç Paylaş

Dosya Giriş Ekle Tasarım Geçişler Animasyonlar Slayt Gösterisi Gözden Geçir Görünüm Acrobat Ne yapmak istediğinizi söyleyin

Yapıştır Yeni Slayt Bölüm Slaytlar Yazı Tipi Paragraf Çizim Yerleştir Hızlı Stiller Şekil Efektleri Şekil Doldusu Şekil Anahattı Şekil Efektleri Bul Değiştir Seç PDF oluşturma Ekleniler

1

2

3





4

5

6

7

8





Acil Sağlık Hizmetlerinin Yapı Taşları

Saha koordinasyonundan hastane içi önceliklendirmeye kesintisiz bir akış.

Saha - 112 Ambulans

112 Koordinasyon Merkezi



A/B/C Tipi İstasyon Ağı



Olay Yeri En Yakın Ekip



Hastane - Triyaj

Kırmızı: Acil Hayati Tehlike

Sarı: Geciktirilemez
Müdahale

Yeşil: Hafif
Yaralanma/Hastalık



Tarife İndirimleri ve 8 Yıllık Geçiş Takvimi

Asimetrik Muafiyetler ve Hassas Ürün Stratejileri

Şimdi bir ara odasındasınız

Başlangıç Anı (1 Ağustos 2015)

Tarife cetvellerinin %70'i anında sıfırlandı.

Geçiş Sürecinin Sonu (8. Yıl)

İhracatta %99 Muafiyet

İthalatta %86 Muafiyet

Sanayi Ürünleri

2018 itibarıyla Malezya vergilerinin %80'i kalktı, 8. yılda tam sıfırlanma taahhüdü.

Tarım Ürünleri

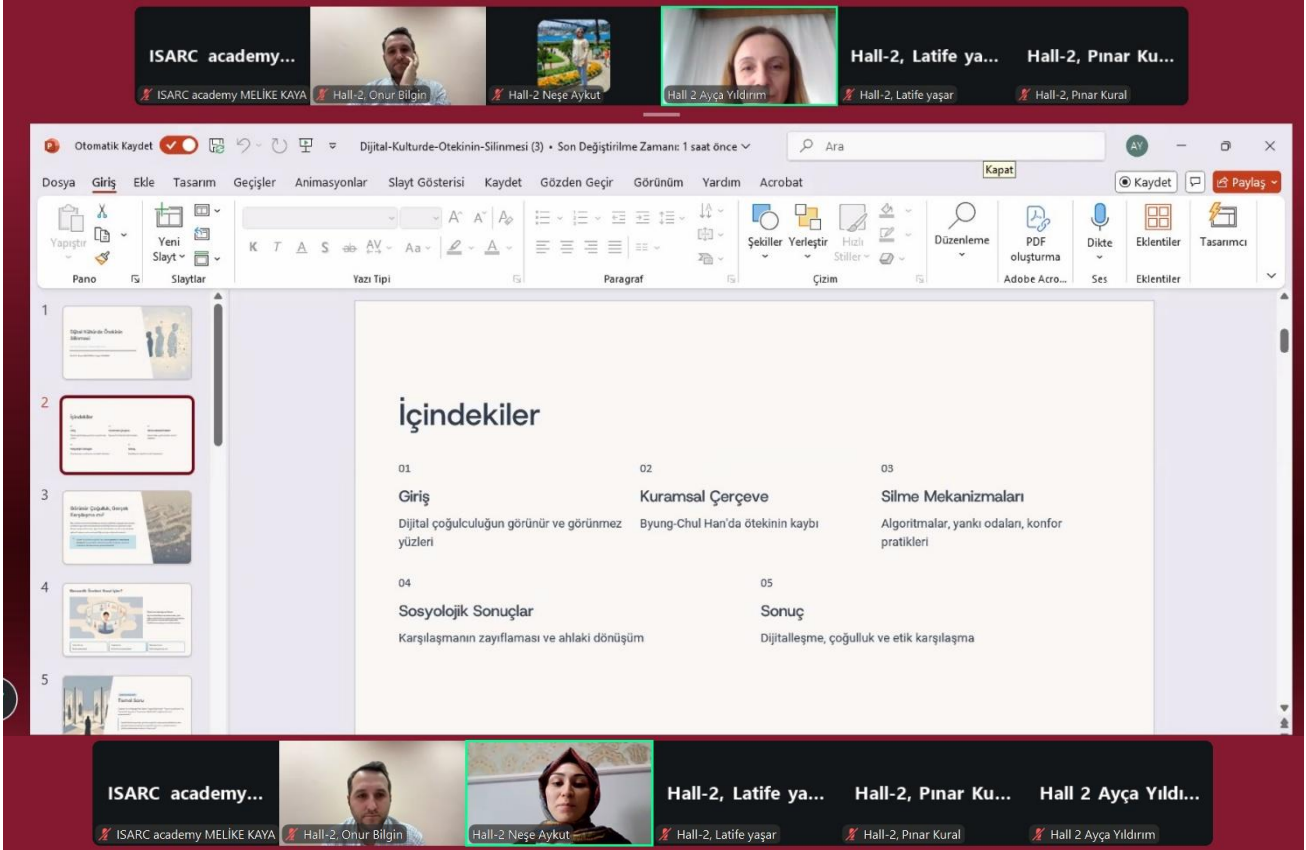
Nar, kavun, karpuz hariç 2018'de sıfırlama. Hassas hayvansal ürünlerde tarife kotaları.

Kritik İndirim: Palm Yağı

Gümrük vergisi korumacı bir reflekse rağmen %31,2'den %21,8'e düşürüldü.

Kapsam Dışı

Alkol, tütün mamulleri, pirinç.



GİRİŞ

- Epilepsi, dünyada her yaşta yaklaşık 50 milyon insanı etkileyen ciddi bir nörolojik bozukluktur (WHO, 2024).
- Sinir sistemi hastalıkları içerisinde en sık görülen 4. hastalık olup ve tekrarlayan nöbetlerle karakterize davranışsal veya motor bozukluklardır (Milligan, 2021; Fiest ve ark., 2017).
- Epilepsinin temel mekanizması, nöronların aşırı uyarılması ve aşırı senkronize nöronlar arasında tekrarlayan sinaptik bağlantıların oluşmasıdır (Rafli ve ark., 2023).

zoom Workplace Meeting Hall-6, SS-2, Dr. Duong To Quoc 1

1th INTERNATIONAL KÜLTEPE SCIENTIFIC RESEARCH AND INNOVATION CONGRESS

Date: 23.3.2026 / Hall-6, Session-2
 Ankara Local Time: 10:30 – 12:00 / Vietnam Time: 14:30 – 16:00
 Meeting ID: 847 4217 4227 / Passcode: 074224

HEAD OF SESSION: Dr. Duong To Quoc THAI

Article Title 1

DEVELOPING HISTORICAL COMPETENCIES FOR HIGH SCHOOL STUDENTS THROUGH PROJECT-BASED LEARNING: A CASE STUDY OF THE 'INDUSTRIAL REVOLUTIONS' TOPIC IN VIETNAM

M.A. Trần Thị HIỀN, Nguyễn Thị Phương HUỖNH, Nguyễn Thị Thu GIÀU, and Duong To Quoc THAI_Dong Thap University, Vietnam

Participants: 6

Audio Video Participants Chat React Share Host tools Breakout rooms More Leave room

Hall-6, SS-2, Dr... ISARC academy...

Hall-6, SS-2, Dr... ISARC academy UMIDA MAVLYANOVA

Hall-6, Ss-2, Dư... Hall-6, SS-2, M...

Hall-6, Ss-2, Duong Văn Triêm Hall-6, SS-2, M.A. Tran Thi HIEN

Hall-6, Ss-2, Nguyen Thi Phuong HU... Hall-6, Ss-2, Nguyen Thi Vu Lan

zoom Workplace Meeting Beghdadi fedwa's screen

seminaire la critique.pptx - PowerPoint

Isolation and purification of actinobacteria from Saharan soils

Sampling → Eight samples → Isolation → Purification → Preliminary Gender Identification → Results

Isolation: Vitamin-B chitin medium, with or without the addition of antibiotics

Purification: 80 strains of actinobacteria were selected and purified on ISP2

Results:

- 5 genera of which 4 genera are rare.
- Streptomyces* (dominant)
- Nocardia*
- Saccharothrix*, *Actinomadura*
- Nocardicopsis*

Participants: 2

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zoom Workplace Meeting DOUIRI NARIJSE's screen

CHALLENGES

ENVIRONMENTAL CHALLENGES

OBJECTIVES

ECONOMIC OBJECTIVES

OUR CHALLENGES

- TECHNICAL**
Battery degradation
Power generation
- ENVIRONMENTAL**
CO2 emissions
- ECONOMIC**
cost

OUR OBJECTIF

A good EMS garante the optimisation multi-criteria

5

DOUIRI NARIJSE

DOUIRI NARIJSE

Audio Video Participants Chat React Share Host tools Breakout rooms More Leave room

14°C Kamen güneşli Ara TUR 10:38 AM 3/23/2026

zoom Workplace Meeting DOUIRI NARIJSE's screen

Microgrid Intelligence Optimized: Enhancing Battery Health & Solar Forecasting

Battery State of Health (SOH) Optimization

INITIAL STATE (Standalone) vs. OPTIMIZED RESULT (Transfer Learning)

OPTIMIZED RESULT (Two-Stage Transfer Learning)

45% to 52% IMPROVEMENT in RMSE

Achieved robust field accuracy with error rates BELOW 3.5% FIELD RMSE

Battery SOH: < 3.5% Field RMSE (Optimized from Standalone)

PV Generation Forecasting

INITIAL STATE (Standalone) vs. OPTIMIZED RESULT (Hybrid Architecture)

OPTIMIZED RESULT (Hybrid GRU-XGBoost Architecture)

43.8% IMPROVEMENT in Forecasting Precision

Achieved a FINAL nRMSE of only 4.17%

PV Forecasting: 4.17% Final nRMSE (Optimized from Standalone)

DOUIRI NARIJSE

DOUIRI NARIJSE

Audio Video Participants Chat React Share Host tools Breakout rooms More Leave room

14°C Kamen güneşli Ara TUR 10:40 AM 3/23/2026

zoom Workplace Meeting Beghdadi fedwa's screen

antimicrob molécules bioactives (renregistrement automatique).pptx - PowerPoint

Table(01). Examples of **antibacterial** molecules produced by **actinobacteria**.

Antibacterial compound producing species	Bioactive compound(s)	Antibacterial compound producing species	Bioactive compound(s)
<i>Streptomyces anulatus</i>	Actinomycins	<i>Streptomyces griseus</i>	Cycloheximide
<i>Streptomyces canus</i>	Amphotericin	<i>Streptomyces orchidaceus</i>	Cycloserine
<i>Micromonospora spp.</i>	Anthracycline	<i>Streptomyces roseosporus</i>	Daptomycin
<i>Streptomyces canus</i>	Aspartocins	<i>Micromonospora purpurea</i>	Gentamicin
<i>Streptomyces avermitilis</i>	Avermectin	<i>Streptomyces kanamyceticus</i>	Kanamycin
<i>Streptomyces venezuelae</i>	Chloramphenicol	<i>Streptomyces mediterranei</i>	Rifamycin
<i>Micromonospora spp.</i>	Clotrimazole	<i>Streptomyces griseus</i>	Streptomycin

14°C Kramen güneşli

Beghdadi fedwa's network bandwidth is low



zoom Workplace Meeting Beghdadi fedwa's screen

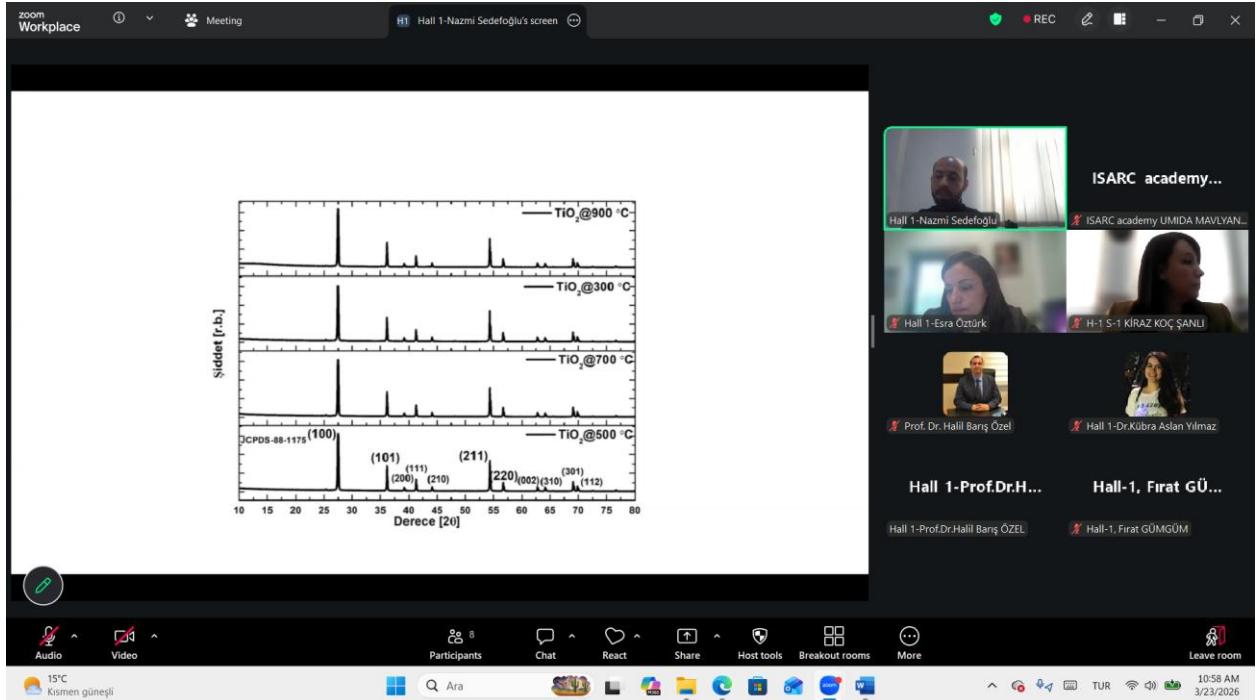
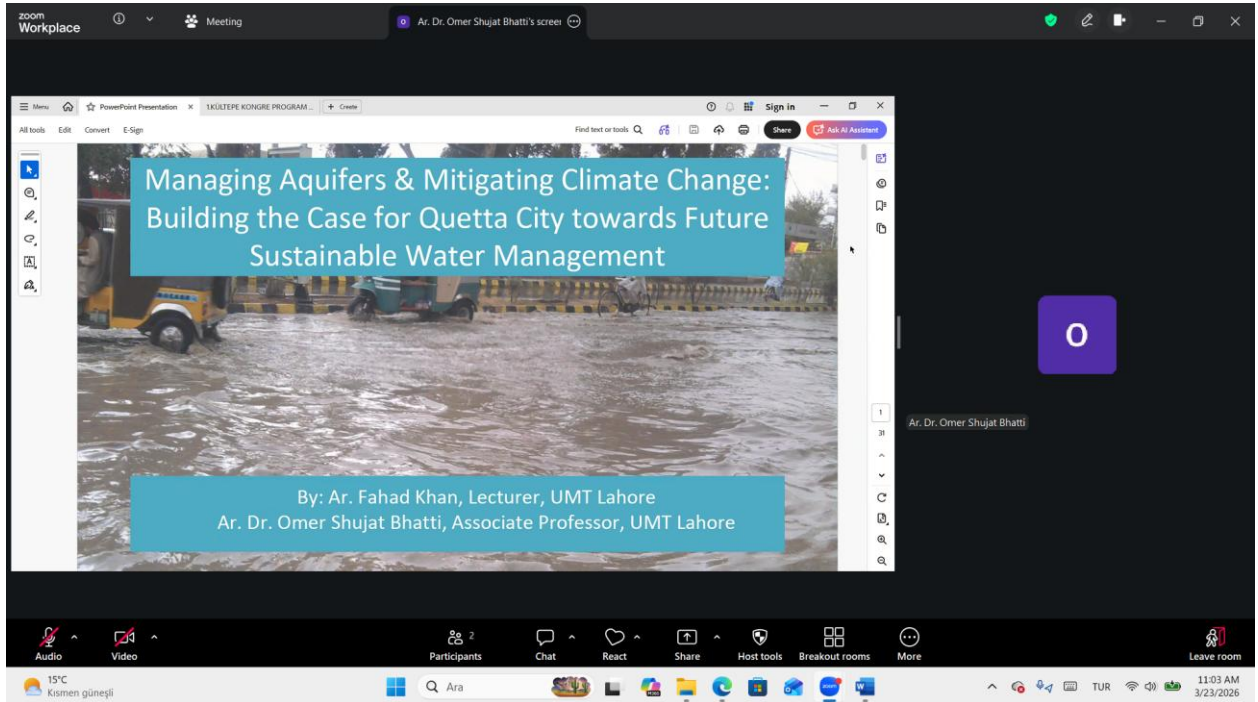
mycotaxines.pptx - PowerPoint

Martials and Methods.

❖ The isolation of phytopathogenic fungi is carried out on PDA medium, incubation at 30°C for 5 days.

14°C Kramen güneşli



Zoom Meeting: Ar. Dr. Omer Shujat Bhatti's screen

Managing Aquifers & Mitigating Climate Change:
 Building the Case for Quetta City towards Future
 Sustainable Water Management

By: Ar. Fahad Khan, Lecturer, UMT Lahore
 Ar. Dr. Omer Shujat Bhatti, Associate Professor, UMT Lahore

Ar. Dr. Omer Shujat Bhatti

15°C Kamen güneşli Ara 11:03 AM 3/23/2026

zoom Workplace Meeting Ar. Dr. Omer Shujat Bhatti's screen

PowerPoint Presentation x 1KULTEPE KONGRE PROGRAM ...

Introduction

- Water scarcity means a shortage in availability due to physical shortage or scarcity.
- Around 33% of the earth's major aquifers are being depleted unsustainably.
- Nearly 40% of the world's population is suffering from water scarcity.
- Globally around 50% of urban water use is associated with well, spring and borehole sources.

Impacts of urbanisation

- Surface waterways
 - Peak runoff
 - Deterioration in quality
- Groundwater systems
 - Radical change in aquifer recharge patterns and rates.
 - Negative quality recharge.

Interaction between urban services through the underlying groundwater system. (Foster, 2001)

Ar. Dr. Omer Shujat Bhatti

15°C Kamen güneşli Ara

11:04 AM 3/23/2026

zoom Workplace Meeting Ar. Dr. Omer Shujat Bhatti's screen

PowerPoint Presentation x 1KULTEPE KONGRE PROGRAM ...

Introduction

- Quetta is the provincial capital of Balochistan.
- 1680 meters above sea level.
- Valley watershed area: 1756km²
- The valley is divided in two basins; Quetta valley in the north and Dasht plain in the south.
- Groundwater levels declining at an alarming rate, Land subsidence.
- Increase in population, refugees
- Electricity subsidies for agriculture
- Illegal tubewell drilling
- Fluctuations in the precipitation
- Drought

Average monthly temperature and rainfall (source: weather-atlas.com)

Water decline map of Quetta City. Redrawn from (Kakar et al., 2016)

Ar. Dr. Omer Shujat Bhatti

15°C Kamen güneşli Ara

11:05 AM 3/23/2026

zoom Workplace Meeting Ar. Dr. Omer Shujat Bhatti's screen

PowerPoint Presentation x 1KULTEPE KONGRE PROGRAM... + Create

Understanding the context Of Quetta

10 of 31

Ar. Dr. Omer Shujat Bhatti

Audio Video Participants Chat React Share Host tools Breakout rooms More Leave room

15°C Kamen güneşli Ara TUR 11:07 AM 3/23/2026

zoom Workplace Meeting Reashmi S (hall 2)'s screen

The Digital Crime Landscape

The rapid growth of digital technologies has led to a significant increase in cybercrimes including hacking, identity theft, financial fraud, and data breaches. Traditional investigation methods are insufficient for handling these complex cases.

Digital forensics has emerged as a critical discipline, enabling investigators to identify, collect, analyze, and preserve digital evidence while ensuring its integrity.

Reashmi S (hall 2)

Reashmi S (hall 2)

Made with GROWMAN

Audio Video Participants Chat React Share Host tools Breakout rooms More Leave room

15°C Kamen güneşli Ara TUR 11:18 AM 3/23/2026



INTERNATIONAL SCIENCE AND ART RESEARCH CENTER

KONU: Kongre Katılımcı Bilgisi

28.03.2026

İLGİLİ MAKAMA

1.ULUSLARARASI KÜLTEPE BİLİMSEL ARAŞTIRMALAR VE İNOVASYON KONGRESİ 23-24 MART 2026 tarihleri arasında KAYSERİ 'de online olarak 12 farklı ülkeden (Türkiye:12 ve diğer Ülkeler:24 Toplam:36 akademisyen/araştırmacıların katılımı ile gerçekleşmiştir. Kongre, 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen '' Tebliğlerin sunulduğu yurt içinde veya yurtdışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışından en az 5 ülkeden farklı tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır. '' değişikliğine ve Doçentlik kriterlerine uygun düzenlenmiştir.

Bilgilerinize arz edilir.

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Sefa Salih BİLDİRİCİ
HEAD OF İSARC

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BAZI ETKİLİ MİKROORGANİZMALARIN (EM-1 VE EM-5) DOĞU GÜRGENİ (*Carpinus orientalis* Mill.) TOHUMLARININ ÇİMLENME PARAMETRELERİ ÜZERİNE ETKİLERİ**Kadir Can GÜLEÇ**

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Ormanların çok sayıda canlı ve cansız unsurun kendi içinde ve karşılıklı etkileri sonucunda oluşmuş dinamik bir ekosistemdir. Bu ekosistem dışarıdan gelen etkilere karşı doğal süreçler çerçevesinde daima sahip olduğu ekolojik dengenin devamlılığının sağlamaya çalışmaktadır. Bu dengenin korunmasında ormanın ev sahipliği yaptığı en önemli unsurların başında gelen ağaçların ayrı bir önemi vardır. Ağaç türlerinin farklı ekolojik ve silvikültürel özelliklerinin olması da bu durumun en önemli göstergesidir. Bu kapsamda bazı ağaç türleri özellikle sahip olduğu odun hammaddesinin dayanıklı olması nedeniyle geniş bir kullanım alanına sahip olması nedeniyle daha sık ve yoğun bir sosyal baskıya maruz kalarak orman kaynaklarından kısa sürede uzaklaştırılmaktadır. Ülkemiz orman kaynakları da tür çeşitliliği açısından zengin ve çeşitli olmakla birlikte doğu gürgeni (*Carpinus orientalis* Mill.) bazı ağaç türleri yaygın kullanım alanları nedeniyle çok fazla sömürülmüş ve nesli tehlike altına girmiştir. Doğü gürgeni fonksiyonel açıdan değerli bir ağaç türü olmakla birlikte tohumunun sahip olduğu yüksek çimlenme engeli nedeniyle genç bireylerinin yetiştirilmesi oldukça zor ve güç olan bir türdür. Bu nedenle doğa çok az miktarda sağlıklı tohumları temin edilen bu türün çimlenme yüzdesi ve çimlenme hızı gibi bazı önemli çimlenme parametrelerinde daha yüksek verimliliğin sağlanabilmesi için doğal olarak yaşamın içinde bulunan ve doğada doğal olarak sentezlenen bazı etkili mikroorganizmaların (EM-1 ve EM-A gibi) etkilerinin incelenmesi amacıyla bu araştırma gerçekleştirilmiştir. Araştırma kapsamında soğuk katlama ile çimlenme engeli giderilmiş doğü gürgeni tohumlarına her iki etkili mikroorganizma tipinin 3 farklı dozu (%20, %50 ve %80) uygulanmış ve bu uygulamaların tohumların çimlenme yüzdesi ve çimlenme hızı üzerinde meydana getirdiği farklılaşmalar incelenmiştir. Yapılan çimlenme testlerinden elde edilen ham verilere uygulanan varyans analizi ve Duncan testi sonucunda özellikle %50 konsantrasyon seviyesinden itibaren hem farklı orijinler arasında hem de kontrol tohumları ve diğer konsantrasyon dozları arasında istatistiki açıdan olumlu etkilerin olduğu belirlenmiştir.

Anahtar Kelimeler: Doğü Gürgeni, Tohum, Etkili Mikroorganizma, Çimlenme Parametreleri

EFFECTS OF SOME EFFECTIVE MICROORGANISMS (EM-1 AND EM-5) ON GERMINATION PARAMETERS OF ORIENTAL HORNBEAM (*Carpinus orientalis* Mill.) SEEDS

ABSTRACT

Forests are dynamic ecosystems formed by the interaction of numerous living and non-living elements within themselves and with each other. This ecosystem constantly strives to maintain its ecological balance through natural processes in the face of external influences. Trees, which are among the most important elements in maintaining this balance, play a special role. The fact that different tree species have different ecological and silvicultural characteristics is a key indicator of this. In this context, some tree species, especially due to the durability of their wood and their wide range of uses, are subjected to more frequent and intense social pressure and are quickly removed from forest resources. This situation leads to the endangerment of the species and makes it difficult to ensure their continued existence. Although our country's forest resources are rich and diverse in terms of species diversity, some tree species, such as the oriental hornbeam (*Carpinus orientalis* Mill.), have been heavily exploited due to their widespread uses and are endangered. While the oriental hornbeam is a functionally valuable tree species, its high seed germination barrier makes it quite difficult and challenging to cultivate young individuals. Therefore, this research was conducted to investigate the effects of certain effective microorganisms (such as EM-1 and EM-A) that are naturally occurring and synthesized in nature, in order to achieve higher efficiency in some important germination parameters such as germination percentage and germination rate of this species, for which nature provides very few healthy seeds. Within the scope of the research, three different doses (20%, 50%, and 80%) of both effective microorganism types were applied to oriental hornbeam seeds whose germination inhibition was removed by cold stratification, and the differences in germination percentage and germination rate of the seeds caused by these applications were examined. The results of the variance analysis and Duncan test applied to the raw data obtained from the germination tests showed that statistically significant positive effects were observed, especially from the 50% concentration level onwards, both among different origins and between control seeds and other concentration doses.

Keywords: Oriental Hornbeam, Seed, Effective Microorganism, Germination Parameters

1. INTRODUCTION

Many dynamics have taken place and changed in the process from the formation of the universe to the present day. The living populations that form the basis of these dynamics have contributed to the biological diversity on earth as a result of the interactions they have experienced both

within themselves and with the environment. The most important of this diversity, the flora elements, have ensured the existence of a very rich plant diversity in today's world as a result of the changes they have undergone during the process and have made countless contributions to the ecosystem. One of the most important places of this plant richness is the forests covering an area of 23.2 million hectares (29.6%) in our country. Along with forests, our country, with the presence of various ecological settlements formed as a result of the effects of numerous climatic, edaphic, physiographic and biotic factors, hosts 12,000 plant taxa, 3000 of which are endemic, and with this richness it has, it progresses parallel to the plant species diversity of the European continent and is described as "Asia Minor" (Erik and Tarikahya, 2004; Avcı, 2014; Çuhadar and Alan, 2021).

Oriental hornbeam (*Carpinus orientalis* Mill.) is important as an important species that grows rapidly in forest habitats and sheds leaves. It is very important for the production of both industrially useful products such as paper and non-wood forest products such as charcoal. When wild cherry is grown as part of a tree in the forest, it also has a positive effect on biodiversity due to the nutritional value of its fruit. The monetary value of this species should not be ignored. Tree breeding and genetic protection studies are being carried out in Europe to increase the oriental hornbeam population and encourage afforestation. It is also listed among the "Valuable Leafy Plants" by the European Forest Genetic Resources (EUFORGEN). This situation emphasizes the need for sustainable management of wild cherries and conservation of their diversity (Kulaç et al., 2009). In addition to human damage, due to the high ecological value of the wild cherry individuals that are under pressure due to the high demand for light in our forests, it has become a rare species due to its secondary tree species. For all these reasons, we need to give more importance to wild cherry in our forests and afforestation activities. Oriental hornbeam is a deciduous forest tree species that is naturally found in Europe, North Africa, West Asia and our country and has ecological and economic value (Davis, 1972; Savill, 1991; Santi et al., 1998; Russell, 2003). In our country, it is generally widespread along the northern line and although its main distribution area is generally stated as the Black Sea Region and the Northern Marmara Region, it is unlikely to survive in the Aegean, Central Anatolia, Mediterranean, Western and Southern Marmara Regions (Welk, 2016). Several different methods have been tried to eliminate seed germination barriers. These methods include hot-cold stratification, hot water application, various mechanical and chemical processes such as sulfuric acid, citric acid, lye, hydrogen peroxide. However, it has been observed that hot and

cold stratification is predominant in practice and other mechanical and chemical processes do not show the desired success (Anon., 1989; Kulaç, 2009).

Some microorganism studies have been conducted on wild cherry seedlings and it has been concluded that higher quality seedlings are obtained thanks to microorganisms on seedlings. (Klymenko et al., 2010). Based on this, it has been seen that sustainable seedlings can be obtained as a result of the use of Effective Microorganisms to improve germination parameters on seeds and eliminate germination barriers, and indeed, it has been observed that the effects on germination of wild cherry seeds were not examined with the use of effective microorganisms in the study focusing on seedlings.

The effect of Effective Microorganisms has been tested on seeds with low germination values on exotic and forest tree species and on seeds of many agricultural species and positive results have been obtained (Chaudhry et al., 2005; Piskier, 2006; Javaid, 2006). In the light of these studies, it has been determined that these organic compounds, like other chemical substances, do not negatively affect the physiological or anatomical characteristics of seeds, seedlings and saplings, on the contrary, they support their development positively and do not cause environmental pollution due to their natural structure. It is used to increase the resistance of plants to diseases, pests, cold and frost, but Effective Microorganisms (EM) used in the project to remove the germination barrier;

EM-1: It is a product widely used in agriculture and provides all the beneficial properties of EM. EM-5: It is a quality liquid microbial fertilizer and auxiliary plant nutrient. It is applied from the leaves to increase resistance to diseases and pests. When applied continuously, it reduces the need for chemical pesticides to almost zero. It is sprayed after germination to protect against diseases and pests before they appear.

2.MATERIAL AND METHOD

The natural habitats located in the northern regions of Türkiye, such as Kdz.Ereğli, Zonguldak-Dirgine, Karabük-Yenice, Kastamonu-İnebolu and Bartın-Karaçaydere, are areas where biodiversity is rich and human intervention is low. Oriental hornbeam trees in these regions are generally young, healthy and dominant, and they form an important part of the ecological structure of these areas. Forest management directorates work to collect cherry fruits at the most appropriate time and method as a result of the land surveys they conduct in these areas. June is the ideal time for the fruiting period of oriental hornbeam trees. As of June, the fruits ripen and yellowish red, soft and ripe seeds are seen. At least 300 ripe and healthy oriental hornbeam seeds were collected in June in the mentioned regions, and a total of 1600. The collection

process was planned and carried out especially considering the labor force and climate conditions. Therefore, the seed collection dates differed. In this way, it will help us better understand the germination potential of the seeds according to the genetic characteristics and ecological structure of each region. The collected seeds were brought to the laboratory environment and meticulously processed in order to increase the germination ability of the seeds and reduce the risk of possible contamination caused by external factors. Here, the seeds were separated from their seeds in a basin without damaging them, ensuring that the seeds could be used later. The seeds were first separated regionally and then the seeds were gently crushed by hand to remove them. In this way, the processes were carried out meticulously in order to preserve the strength and quality of the seeds. The seeds were completely separated from their flesh, washed with pure water and then dried in a shaded area. In this way, it is applied to eliminate potential pathogens on the surface of the seeds. This process is important for ensuring the healthy germination and growth of the seeds. In order to purify the seeds from external factors and ensure their longer storage, the dried seeds were stored in cloth bags in a cool and airy environment. In this way, it was aimed to maintain the optimum moisture level of the seeds and preserve their quality. Thus, the preliminary preparation of the wild cherry seeds to produce quality saplings was made in this way. In addition, it is an important step taken to protect the natural genetic diversity of the seeds and to support forestry activities. The steps implemented in this process were meticulously planned in accordance with scientific standards and were carried out with the aim of contributing to the sustainable use of natural resources. In order for germination tests to yield more reliable results, seeds were subjected to quality control. In order to evaluate the vital activities of the seeds, vitality tests were performed and seeds with low germination potential were identified and eliminated before participating in the testing process, and then germination test procedures were initiated.

Solutions were prepared in 1.5 liter containers for EM-1 and EM-5 20%, 50%, 80% (adjusted as low, medium and high doses). Then, the seeds were placed in containers in which they would be kept. Before the seeds were placed, moistened germination papers were placed in the petri dishes and the seeds were placed on these germination papers so that they would not touch each other. A total of 100 seeds were subjected to germination in 4 petri dishes, 20 seeds in each container. These processes were carried out separately for 5 different origins. Germination checks were made on the 7th, 14th, 21st days after the seeds were placed in the refrigerator and then periodically every day. This is important to monitor the development of the germination process, to detect potential deviations and to ensure the accuracy of the data. After the seed

germination process was completed, the germination percentage was calculated by dividing the number of germinated seeds by the number of seeds planted. The germination rate is known as the number of seeds germinated in the first 7 days after the processes on the seeds begin. Therefore, the germination rate is taken into account as the percentage (%) of the number of seeds germinated in the first 7 days. In this research, the tests were performed in the same way for each origin in the control. Although these tests were performed for each origin, control samples were prepared in petri dishes from 5 different origins where seeds were taken and it is a necessary step to ensure that the results obtained reflect the original seed characteristics and to minimize the possibility of external factors affecting the results. In this way, the effects of EM types and doses were easily revealed with statistical comparisons. There are statistical tests to be performed in the research within the scope of the project in order to interpret the results. At the end of the research, one-way variance analysis was performed to determine the differences between the 5 different origins and EM types concentrations. Then, Duncan test was used for groupings and SPSS statistical package program was used for these.

3.RESULTS AND DISCUSSIONS

Findings regarding the germination rate and germination percentage parameters of oriental hornbeam seeds with the application of solutions prepared at different doses of EM1 and EM5 effective microorganisms are presented in tables below.

Table 1. Duncan Test Results for Germination Rate of Seeds in EM-1 Solutions

Provenances	Doses			
	Control	%20	%50	%80
Zonguldak Kdz.-Ereğli	33,47	43,37 ^{bc}	51,47 ^{ab}	62,19 ^{ab}
Zonguldak-Dirgine	31,78	39,91 ^{bc}	48,01 ^b	60,15 ^{ab}
Karabük-Yenice	43,56	59,67 ^c	57,07 ^b	71,81 ^a
Kastamonu-İnebolu	34,71	51,70 ^{bc}	46,13 ^{ab}	70,46 ^a
Bartın-Karaçaydere	30,63	37,95 ^{bc}	45,57 ^{ab}	58,62 ^c

Table 2. Duncan Test Results for Germination Rate of Seeds in EM-5 Solutions

Provenances	Doses			
	Control	%20	%50	%80
Zonguldak Kdz.-Ereğli	35,27	43,31 ^b	57,04 ^{ab}	64,74 ^a
Zonguldak-Dirgine	32,88	40,41 ^c	55,44 ^{bc}	63,08 ^{ab}
Karabük-Yenice	45,75	54,91 ^c	67,42 ^{bc}	75,85 ^b
Kastamonu-İnebolu	36,87	45,97 ^{bc}	59,34 ^{ab}	66,13 ^a
Bartın-Karaçaydere	32,99	41,26 ^{bc}	52,33 ^b	59,98 ^a

When the germination rate is examined in the studies conducted, as seen in Table 1 and Table 2, the most significant result for EM-1 and EM-5 is seen in 80% dose. Although this rate

gradually decreases in the other 50% and 20% doses, it is seen that it has a higher germination rate compared to the control group in the tests conducted using EM-1 and EM-5. At the same time, when we look at the origins of EM-1 and EM-5, although the highest germination rate in the control group is seen as Karabük-Yenice, the highest germination rate value is seen in the same provenance in 90% solution. In the germination percentage variable, although this rate gradually decreases in 30% and 60% doses, higher germination percentage was observed in tests performed using EM-1 and EM-A compared to the control group. At the same time, when we look at EM-1 and EM-A origins, the best germination rate in the control group is seen as Karabük-Yenice, although the germination percentage in 90% solution is seen as the highest value in same origin. Similar results were obtained from other studies conducted using the same doses of similar effective microorganisms on seeds of Wild Cherry, Scots Pine and Black Pine species.

4.CONCLUSIONS

According to the scientific findings obtained, according to the study conducted on oriental hornbeam populations, it is seen that there are differences in seeds taken from origins depending on geographical and ecological (altitude, rainfall) factors. In this study where different populations, solutions and doses are examined, when the germination rate and germination percentage are examined, it is seen that the highest statistically significant result is obtained in EM-1 effective substance. In this respect, in terms of sustainability on the species, the use of effective microorganisms to encourage the elimination of germination barriers is important. The production and breeding studies of this species, which is important for non-wood forest products and wildlife, will contribute to us in every way. Within the scope of this study, although the origins are different, it is seen that effective microorganism species are effective in eliminating germination barriers.

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FE₂O₃ NANOPARTİKÜLÜNÜN GÜMÜŞİ IHLAMUR (*Tilia tomentosa* Moench.) FİDANLARININ BAZI FİZYOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİSİ**Halil Barış ÖZEL**

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Dünyanın doğal olarak kendisini yenileyebilen en önemli kaynağı olan ormanlar, günümüzün en önemli çevre sorunu olan küresel ısınmanın olumsuz etkilerinin azaltılması açısından da vazgeçilmez bir öneme sahiptir. Ancak çok kompleks ve dinamik bir yapıya sahip olan bu canlı varlık son yıllarda çok sayıda biyotik ve abiyotik faktörlerin etkisi, aşırı faydalanma ve yangınlar, ağır metal ve nanopartiküler kirlilik gibi nedenlerle önemli ölçüde azalmış, kalite ve sağlık durumları önemli ölçüde zayıflayarak verim güçleri düşmüştür. Bu nedenle degrade hale gelmiş ve verim güçleri azalmış olan ormanların yeniden verimli hale getirilerek yeniden milli ekonomiye kazandırılması oldukça önemlidir. Ülkemizin önemli orman ağacı türlerinden birisi olan Gümüşi Ihlamur (*Tilia tomentosa* Moench.) ormanlarında da bu önemli verim düşüşü son yıllarda belirgin olarak yaşanmaktadır. Özellikle endüstriyel üretim süreçleri sonrasında yaygın olarak yaşam ortamlarında bulunan ve tüm canlıların yaşam süreçlerini olumsuz etkileyen nanopartikül türlerinden birisi olan Fe₂O₃ nanopartikülünün bu araştırma ile farklı dozlarda hazırlanan konsantrasyonlarının klorofil a, klorofil b ve fotosentez gibi önemli fizyolojik özellikleri üzerindeki etkileri incelenmiştir. Yapılan uygulamalar sonucunda 2+0 yaşındaki ihlamur fidanlarından elde edilen verilere uygulanan varyans analizi ve Duncan testi sonucunda hem konsantrasyonlar arasında hem de kontrol fidanları arasında %95 güven düzeyinde istatistik açıdan önemli farklılıklar bulunmuştur. Buna göre özellikle 1000mg/l dozdan itibaren klorofil a, klorofil b ve fotosentez miktarında %35-58 oranında azalmanın meydana geldiği ve bu konsantrasyon düzeyinin toksik eşik meydana getirdiği saptanmıştır.

Anahtar Kelimeler: Fe₂O₃ Nanopartikülü, Fidan, Fizyoloji, Gümüşi Ihlamur, Toksik Etki**THE EFFECT OF FE₂O₃ NANOPARTICLES ON SOME PHYSIOLOGICAL CHARACTERISTICS OF SILVER LINDEN (*Tilia tomentosa* Moench.) SEEDLINGS
ABSTRACT**

Forests, the world's most important naturally regenerating resource, are indispensable in mitigating the negative effects of global warming, one of the most significant environmental problems of our time. However, these complex and dynamic living organisms have significantly decreased in recent years due to the influence of numerous biotic and abiotic factors,

overexploitation and fires, and heavy metal and nanoparticle pollution. Their quality and health have deteriorated considerably, and their productivity has decreased. Therefore, it is crucial to restore degraded and degraded forests to their productive state and reintegrate them into the national economy. This significant decline in productivity has also been observed in recent years in the forests of the Silver Linden (*Tilia tometosa* Moench.), one of the important forest tree species in our country. This research investigated the effects of Fe₂O₃ nanoparticles, a type of nanoparticle commonly found in habitats after industrial production processes and negatively affecting the life processes of all living things, on important physiological properties such as chlorophyll a, chlorophyll b, and photosynthesis, using different concentrations. Analysis of variance and Duncan test applied to data obtained from 2+0 year old linden seedlings as a result of the applications revealed statistically significant differences at the 95% confidence level, both between concentrations and between control seedlings. Accordingly, it was determined that a decrease of 35-58% in chlorophyll a, chlorophyll b and photosynthesis amounts occurred, especially from the 1000 mg/l dose onwards, and that this concentration level constituted the toxic threshold.

Keywords: Fe₂O₃ Nanoparticle, Seedling, Physiology, Silver Linden, Toxic Effect.

1.INTRODUCTION

Nanoparticles (NPs) are extremely small particles, typically less than 100 nanometers in size, and they are increasingly used in various industrial, agricultural, and environmental applications. However, the effect of pollution from nanoparticles on plants is a growing concern as they can enter the plant system through various means such as the soil, water, and air. Here's how pollution from nanoparticles can affect plants; Nanoparticles can have toxic effects on plant cells by entering through root absorption or foliar uptake (when deposited on the surface of leaves). Once inside the plant, nanoparticles can; Cause oxidative stress: NPs may generate reactive oxygen species (ROS) that damage plant cells by breaking down lipids, proteins, and nucleic acids, leading to cell death and reduced plant growth. Disrupt cellular functions: Nanoparticles can interfere with processes like photosynthesis, respiration, and nutrient uptake, potentially leading to stunted growth or chlorosis (yellowing of leaves). Some nanoparticles, particularly metal-based ones like silver, copper, and zinc, can disrupt the photosynthetic machinery in plants (Du et al., 2010; Andreotti et al., 2015). They can; Damage chlorophyll: Nanoparticles can interfere with chlorophyll content, which reduces the plant's ability to capture light energy and convert it into chemical energy. Block stomatal openings: By clogging the stomata (tiny pores on the leaf surface), nanoparticles may limit gas exchange, further

hampering photosynthesis. Roots are especially vulnerable to nanoparticles due to their direct contact with soil and water. Some of the effects include;

- Reduced root growth: Exposure to nanoparticles can cause a decrease in root length and surface area, reducing the plant's ability to absorb water and nutrients.
- Toxic accumulation in root cells: Toxic nanoparticles can accumulate in root tissues, damaging root cells, leading to necrosis (cell death), and reducing overall plant health.
- Nanoparticles can interfere with the plant's ability to take up essential nutrients from the soil;
- Disruption of nutrient uptake: Some nanoparticles can block the transport of nutrients like nitrogen, phosphorus, and potassium, leading to deficiencies that affect plant growth and development.
- Bioaccumulation of harmful substances: Heavy metals present in nanoparticles (such as cadmium or lead) may accumulate in plant tissues, posing potential risks to the plant and, eventually, the food chain.

Plants rely on beneficial microorganisms (such as mycorrhizae) for nutrient uptake and overall health. Nanoparticles can negatively affect these interactions;

- Toxic effects on soil microbes: Some nanoparticles can kill or inhibit soil microorganisms essential for nutrient cycling, thereby reducing soil fertility and plant growth.
- Altered root microbiome: Exposure to nanoparticles can alter the composition of the plant's root microbiome, which could affect nutrient availability and plant health.

Nanoparticle pollution can affect plant reproduction;

- Reduced seed viability: Exposure to nanoparticles may decrease seed germination rates and lead to the production of weaker, less viable seeds.
- Pollination interference: Some studies suggest that nanoparticles deposited on flowers or leaves could interfere with pollinator behavior, indirectly affecting plant reproduction (Dietz and Herth, 2011; Liu et al., 2016).

Bioaccumulation in the food chain: As plants absorb nanoparticles, these particles can enter the food chain. Herbivores consuming contaminated plants may accumulate nanoparticles, which could impact animal health.

Soil contamination: Persistent nanoparticles can accumulate in the soil over time, leading to long-term environmental pollution and impacting plant health for future generations. While nanoparticles have many beneficial uses, their pollution can pose significant risks to plant health, affecting growth, reproduction, and ecosystem stability. Understanding how different types of nanoparticles affect plants is crucial for developing strategies to minimize the negative impacts on agriculture and the environment. Further research is needed to better assess these effects and to explore ways to mitigate the risks associated with nanoparticle pollution.

2.MATERIAL AND METHOD

2.1. Material

Silver Linden (*Tilia tomentosa* Moench.) is one of the important forest trees of our country and can be evaluated in many different ways. It is known that oriental beech covers 3,45% of the forest areas in Türkiye and spreads over an area of 675.328 hectares. (OGM, 2020) This species generally enjoys the effect of the maritime climate, that is, the temperature in the summer months usually does not exceed 22°C and the winters are not too cold. Silver Linden can grow well under shade and therefore generally prefers the north and northwest directions. It prefers well-drained, high-sloping and airy soils. It is also a species sensitive to soil properties. (Saatçioğlu, 1976). Silver Linden is a tree species from the beech family and is frequently found in the mountainous regions of the Middle East and Eastern Europe. This tree species is important for different purposes such as wood production, landscaping and habitat provision while preserving biodiversity. The characteristics of silver linden seedlings include various factors that directly affect plant health and growth. In our country, the widest distribution area of oriental beech is observed in the Black Sea forests. However, it is found locally in Northern, Western and Southern Anatolia and the Marmara Region. While the tree height of silver linden generally varies between 30-40 meters, the trunk middle diameter is 1.0-1.5 meters and the usable stem height is around 15-20 meters (Bozkurt and Erdin, 2011; Erdin and Bozkurt, 2013).

Fe₂O₃ nanoparticle used in the study were prepared with four different concentrations (700 mg/l, 1000mg/l, 1300mg/l and 1600mg/l) of pure water. The concentrations prepared in the laboratory environment were taken to Gökçebey Nursery to be applied. In the application, 3 repetitions were carried out for each concentration level of each nanoparticle type. For each of the 3 repetitions, 30 seedlings and a total of 90 seedlings were applied for each concentration level. Thus, 360 seedlings were used for each nanoparticle type. The study was carried out on 90 of 2+0 aged covered silver linden seedlings in a total of 3 repetitions, including control samples that were not subjected to any nanoparticle application as the control group. In the field phase, different concentrations of nanoparticles were applied on 2+0 old covered seedlings in the nursery in the morning dawn after the late frosts passed and before the vegetation season began. These measurements were also repeated three times at the beginning, middle and end of vegetation. In these measurements made at intervals, the amount of photosynthesis, chlorophyll a and chlorophyll b variables were taken into account.

2.2. Method

In measuring physiological parameters, a LICOR brand device was used as a photosynthesis device. In chlorophyll a and b measurements, healthy leaves of silver linden saplings were collected; chlorophyll a and b measurements were started in the laboratory environment. Chlorophyll analysis determination: The leaves of the saplings whose chlorophyll amounts will be measured are taken, crushed in a mortar and a solution is created with ethanol (25 ml ethanol for 1 gr pure chlorophyll) and the chlorophyll amounts in this solution are determined using the photoelectrocolorimetry (FEK-M) method (Dmitriyeva and Kefeli, 1991). This method allows us to determine the density (optical frequency) of the chlorophyll amount in the plant. FEK-M measures the difference between the electrical current strengths of two different rays with the help of a galvanometer and the optical frequency of the solution is determined. The appropriate filter is selected from among four different filters according to the color of the solution used (Red filter was used). A calibration curve was created according to the values read on the galvanometer for the standard. Three repeated readings are made to determine the concentration of the solution. The values read on the galvanometer are calculated with the help of a column on the calibration curve. The amount of chlorophyll is obtained according to the amount of density. The “hetri” solution is used to compare the used solution (Dutton et al., 1943; Atik, 2008). Variance analysis will be used to compare the types of nanoparticles and the 4 different concentrations applied to each type of nanoparticle in terms of photosynthesis amount, chlorophyll a and chlorophyll b, and the Duncan test was applied to create homogeneous groups. All these statistical analyses were performed with the help of the SPSS statistical package program.

3.RESULTS AND DISCUSSIONS

The results of data of physiological variables performed on beech saplings at the beginning, middle and end of the vegetation period are given separately in the tables below.

Table 1. Intro-Vegetation Period of Photosynthesis Amount, Chlorophyll a and b Measurements of Seedlings to Fe₂O₃ Concentrations were Applied

Variables	Concentration doses (mg/l)				
	Control	700	1000	1300	1600
Amount of Photosynthesis (µmol)	11,24	14,12	15,57	13,21	13,74
Chlorophyll a (micrograms/milliliter)	7,63	8,52	9,12	8,92	8,15
Chlorophyll b (micrograms/milliliter)	6.47	7,65	8,59	7,88	6,55

In the study where Iron Oxide nanoparticles were used, as seen in Table 1, as a result of the variance analysis performed to determine whether there is a statistically significant difference ($p < 0.05$) between individuals, it is seen that there is no statistically significant difference between individuals in terms of photosynthesis amount at at least 95% confidence level when compared with the control group at different concentrations. In addition, there are no significant differences between chlorophyll a and b values.

4. CONCLUSIONS

In the light of the findings obtained from the research, iron oxide nanoparticles do not affect the physiological characteristics of silver linden very negatively at low initial doses, but they also gave signals that negative effects may start with some minor losses in the performance of these properties. However, significant decreases especially in photosynthesis amounts started to occur starting from 1000 mg and 1300 mg doses. This situation showed that these two dose levels are important toxic threshold values in the normal development performance of the seedlings physiologically. This situation showed that the physiological and morphological characters of the produced seedlings can be negatively affected by the effects of various pollutant sources in open field conditions. In the light of these indicators, the presence, effects and growth performances of pollutants should be periodically evaluated in seedling production centers, especially in nursery conditions where open field production is carried out, with random sampling methods in selected seedlings based on species.

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DIGITAL AGRICULTURE AND RURAL DEVELOPMENT: A COMPARATIVE ASSESSMENT OF TURKEY IN THE CONTEXT OF SUSTAINABILITY, THE DIGITAL DIVIDE, AND GREEN TRANSFORMATION

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ABSTRACT

Even though the digital agricultural technologies, including artificial intelligence, the Internet of things (IoT), big data analytics, unmanned aerial vehicles, and precision farming systems, are increasing the speed of the agricultural production transformation, the benefits of this transformation remain unevenly distributed across the regions, income groups, and social strata. The current paper examines the alignment of the Agriculture 4.0 elements with the rural development and green transformation goals through the lens of sustainability by positioning Turkey as a comparative case with the global experience through a structured thematic review. The analysis is structured based on four themes, namely, the rural development–digital transformation nexus, sustainability and green transformation results, the digital divide and regional inequalities, and policy and institutional mechanisms, using a systematic search of Web of Science as well as Scopus and ULAKBIM database between 2015 and 2025. The findings affirm that digital agriculture has a significant potential of productivity improvement and environmental sustainability but realising this potential in the small-scale rural enterprise remains contingent on the state of infrastructure, financing, and institutional support. Based on the experiences of Turkey, Europe, and the developing country settings, the paper concludes with five policy recommendations towards an inclusive and green rural transformation.

Keywords: Digital agriculture, rural development, sustainability, digital divide, green transformation..

1. Introduction

Rural communities today face a confluence of structural pressures — climate change, food insecurity, outmigration of labour, and rapidly depleting natural resources — that reinforce one another in ways that no single intervention can fully address. At the intersection of these pressures, the cluster of digital technologies known as Agriculture 4.0 — artificial intelligence, the Internet of Things, big data analytics, unmanned aerial vehicles, and precision farming systems — has emerged simultaneously as a promising solution and a potential new source of inequality. The rural development literature acknowledges this transformative potential while

cautioning that, in the absence of adequate access, capacity, and institutional support, digital transformation risks deepening the very inequalities it promises to resolve (Chambers, 1983; Saleminck et al., 2017).

Viewed through the lens of the Sustainable Development Goals, the articulation of digital agriculture with rural development bridges SDG 2 (zero hunger), SDG 8 (decent work and economic growth), SDG 10 (reduced inequalities), and SDG 13 (climate action) (WCED, 1987; FAO, 2021). Whether these bridges are actually built, however, depends on whether the technologies reach not only large-scale commercial farms but also smallholder family farmers, women producers, and young rural populations — inclusively and equitably.

This paper examines the rural development and green transformation dimensions of digital agricultural technologies through a comparative lens, treating Turkey as a revealing case study in the context of regional inequalities and policy gaps. The remainder of the paper is organised as follows: conceptual framework, methodology, thematic findings and comparative analysis, discussion, and policy recommendations.

2. Conceptual Framework

2.1. Rural Development Paradigms and Digital Transformation

The intellectual history of rural development spans a considerable conceptual distance: from the modernisation-driven growth models of the 1950s, through the participatory approaches of the 1980s, to the multidimensional sustainable development paradigm that has shaped the field since the turn of the millennium (Ellis & Biggs, 2001; van der Ploeg et al., 2000). Chambers's (1983) 'putting the last first' principle remains an analytically indispensable reference: it demands that rural transformation processes be evaluated according to their effects on the most disadvantaged groups, rather than their aggregate or average outcomes. From this perspective, the integration of digital agriculture with rural development is not a technical project but a multidimensional social process that requires the simultaneous empowerment of rural communities across social, economic, and environmental dimensions.

The integration of Agriculture 4.0 into rural development scholarship aligns productively with van der Ploeg et al.'s (2000) multidimensional framework, which distinguishes deepening (improving the productivity of existing resources), broadening (diversifying into non-agricultural income sources), and regrounding (restructuring market and institutional relationships) as distinct but interrelated pathways. Digital tools bear on all three dimensions simultaneously — enhancing production efficiency, enabling rural entrepreneurship, and

repositioning smallholders within supply chains — though the depth of impact varies considerably by context (Wolfert et al., 2017).

2.2. Sustainability and the Green Transformation Framework

The Brundtland Commission's (WCED, 1987) foundational definition of sustainable development — meeting present needs without compromising the ability of future generations to meet their own — has, in the agricultural context, come to encompass soil health, water resources, biodiversity, and climate resilience alongside economic output. Digital agricultural tools contribute directly to these objectives by optimising input use through precision fertilisation and irrigation, reducing chemical applications through early disease detection, and enabling proactive climate risk management through real-time data (FAO, 2021; Ozdemir & Sevim, 2025).

The European Green Deal and the Farm to Fork Strategy have elevated digital agriculture to a constitutive component of the green transformation agenda, directly linking precision farming applications to the targets of a 50 per cent reduction in pesticide use and a 20 per cent reduction in fertiliser use by 2030 (Philip et al., 2017). This framework has become the global benchmark for rural green transformation and continues to shape agricultural policies across a growing number of countries, including Turkey.

2.3. The Digital Divide: Conceptual Layers

The digital divide refers not to a single gap but to a layered structure of inequalities between those with meaningful access to digital technologies and those without. Philip et al.'s (2017) concept of 'two-speed rural digital development' is particularly useful here: it distinguishes a first-order divide (connectivity infrastructure), a second-order divide (digital literacy and skills), and a third-order divide (the differential capacity to translate digital access into concrete improvements in living conditions). Salemin et al. (2017) extended this framework to the rural context and demonstrated systematically how socio-institutional barriers — beyond physical infrastructure deficits — impede rural digital transformation. For smallholder agriculture, these barriers are not incidental frictions but structural features of the landscape.

3. Methodology

This paper adopts a structured thematic review approach (Snyder, 2019), combining the protocol rigour of systematic reviewing with the interpretive flexibility suited to cross-disciplinary synthesis. The literature search was conducted across Web of Science, Scopus, and TÜBİTAK ULAKBİM databases, covering publications from 2015 to 2025 in both English and Turkish. Search terms included 'digital agriculture', 'rural development', 'sustainability', 'digital

divide', 'green transformation', 'Agriculture 4.0', and their Turkish equivalents. Studies without an explicit rural dimension and purely technical engineering papers lacking social or institutional analysis were excluded. To strengthen the comparative analysis of Turkey against the EU and developing-country contexts, institutional reports from FAO, the World Bank, and the OECD were also incorporated.

Selected studies were coded under four analytical themes: (1) rural development and digital transformation alignment; (2) sustainability and green transformation outcomes; (3) the digital divide and regional inequalities; and (4) policy and institutional mechanisms.

4. Findings and Discussion

4.1. Rural Development and Digital Transformation Alignment

The literature consistently documents concrete gains from digital agricultural applications for small-scale rural enterprises across three dimensions: production efficiency, market access, and risk management. IoT-based decision support systems (López-Morales et al., 2021), UAV-assisted crop health monitoring (Schoofs et al., 2020; Pagliai et al., 2022), and big data analytics (Wolfert et al., 2017) have opened up the kind of informational and predictive capacity that was previously the exclusive domain of large commercial operations. In Turkey, the 'Villages of Tomorrow' project — a UNDP–Trendyol partnership — provides a particularly grounded illustration of this potential: six-month pilot data reported labour savings of 20 per cent, fertiliser reductions of 15 per cent, and pesticide reductions of 25 per cent through the use of agricultural climate stations (Ozdemir & Sevim, 2025).

Yet when evaluated against van der Ploeg et al.'s (2000) multidimensional framework, digital agriculture's record is uneven. Evidence of 'deepening' — improving the productivity of existing resources — is relatively robust; evidence of 'broadening' (rural economic diversification) and 'regrounding' (restructuring market relationships in farmers' favour) is considerably thinner. Integrated strategies that would allow rural communities to capture value beyond the farm gate — through cooperative digital marketplaces, for instance — remain underdeveloped in most contexts, including Turkey.

4.2. Sustainability and Green Transformation Outcomes

The environmental sustainability case for digital precision agriculture rests on substantial empirical ground. Campos et al.'s (2020) variable-rate spraying study in vineyards demonstrated that input use can be substantially curtailed without compromising biological efficacy. Schoofs et al.'s (2020) hyperspectral UAV study showed that fire blight could be detected with 85 per cent accuracy before visual symptoms appeared — enabling early

intervention that reduces the need for broad-spectrum chemical treatment. For Turkey, the implications are particularly significant: with agricultural irrigation accounting for approximately 70 to 75 per cent of total national water consumption, IoT-based smart irrigation systems represent a strategic sustainability instrument of the first order.

The European experience with Green Deal-aligned digital farming programmes offers measurable benchmarks: EU member states have recorded documented reductions in carbon footprint, improvements in soil health, and gains in water use efficiency attributable in part to precision digital applications (Philip et al., 2017). Given Turkey's EU accession process and associated alignment obligations, these outcomes represent directly transferable lessons — particularly for strengthening the green components of TKDK and IPARD support mechanisms.

It is worth noting, however, that the social dimension of green transformation receives considerably less attention in the literature than its environmental counterpart. The spread of autonomous harvesting robots (Van Henten et al., 2002) and AI-assisted crop classification systems (Arjenaki et al., 2013) carries the potential to reduce demand for seasonal and low-skilled agricultural labour — creating a tension between 'green' and 'just' transition objectives that rural development policy will need to address explicitly.

4.3. The Digital Divide and Regional Inequalities

4.3.1. Global and EU Experiences

Globally, the digital divide remains the most consequential structural barrier to agricultural digital transformation. FAO (2023) data indicate that only 47 per cent of the world's rural population has access to the internet — a figure that falls below 20 per cent in South Asia and below 15 per cent across much of sub-Saharan Africa. In developing countries, digital agricultural investment tends to cluster around large commercial operations and well-connected regions, generating a 'digital marginalisation' risk that deepens rather than bridges existing rural inequalities (Salemink et al., 2017).

The European experience offers an instructive counterpoint. The EU's LEADER programme and the Digital Agriculture Europe initiative have constructed an integrated policy architecture that links rural broadband expansion, the establishment of digital farming skills centres, and technology subsidies for smallholders within a single coherent framework. Philip et al.'s (2017) UK-based research on rural digital development showed how a two-speed connectivity landscape reproduces and entrenches social and economic divergence between rural

communities. Their core implication — that broadband infrastructure must be treated as a public good and financed accordingly — holds with equal force in Turkey.

4.3.2. Regional Digital Inequalities in Turkey

Turkey presents a particularly stark regional bifurcation in digital agricultural transformation. Enterprises in western Anatolia, the Aegean, and the Marmara region benefit from higher average educational attainment, stronger cooperative infrastructure, well-developed transport networks, and relatively good broadband coverage — all of which accelerate digital adoption. In contrast, rural agricultural enterprises in eastern and south-eastern Anatolia face compounding structural disadvantages: infrastructure deficits, more severe climate conditions, limited capital accumulation, and weaker institutional support (TÜİK, 2016).

According to the 2016 Agricultural Enterprise Structure Survey published by TÜİK, 80.7 per cent of Turkey's agricultural enterprises operate on less than 100 decares (10 hectares). Small scale deepens disadvantage at every layer of the digital divide. At the first level, small-scale farmers are more likely to be located beyond the reach of broadband infrastructure; at the second level, the producer profiles of small family enterprises — typically older, with lower average formal education — make technology adoption structurally more difficult; and at the third level, the fixed costs of digital investment are spread across a much smaller productive base, dramatically reducing the return on adoption relative to larger operations.

A further pattern is worth highlighting: the regions that most effectively leverage digital farming support programmes are precisely those with the densest cooperative networks. Cooperative structures lower the unit cost of technology adoption through collective purchasing, accelerate knowledge diffusion among members, and create a collective institutional capacity to engage with support programmes. This finding carries a clear implication: closing the digital divide in Turkish agriculture will require not only technical infrastructure investment but active investment in cooperative institutional capacity.

4.3.3. Gender and Generational Dimensions of the Digital Divide

The digital divide in rural areas is not a uniform phenomenon — it is a layered structural disadvantage that intersects with gender and generation in ways that compound one another. Rural women producers face significantly more constrained access to digital farming tools than their male counterparts, owing to restrictions on property rights, the burden of unpaid care work, and the weight of traditional social roles. At the same time, the ongoing outmigration of young people from rural to urban areas steadily erodes the digital literacy capacity of rural communities, structurally reproducing the second-order divide across generations. The finding

that women and students constituted the large majority of the 881 participants in the training component of Turkey's 'Villages of Tomorrow' project (Ozdemir & Sevim, 2025) is encouraging: it demonstrates the latent demand and participation capacity of these historically marginalised groups when programmes are designed with their needs in mind.

4.3.4. Comparative Regional Overview

Region / Country Group	Infrastructure Access	Digital Literacy	Policy Inclusiveness
EU (Western Europe)	High / universal coverage	High	Integrated (LEADER, CAP)
EU (Eastern Europe)	Medium / regional variation	Medium	Developing
Turkey (Western)	Medium–high	Medium	Partial (TKDK, IPARD)
Turkey (East/S.East)	Low–medium	Low	Insufficient
Developing countries	Low	Low	Limited / project-based

Table 1. Comparative Digital Divide Indicators (compiled from Philip et al., 2017; Salemink et al., 2017; FAO, 2023; TÜİK, 2016).

4.4. Policy and Institutional Mechanisms

Turkey's 2024–2028 Strategic Plan of the Ministry of Agriculture and Forestry sets out an ambitious digital transformation agenda encompassing a Digital Agriculture Marketplace, IoT-assisted smart irrigation, and drone-based monitoring programmes. TÜBİTAK and KOSGEB-funded research and development programmes, alongside TKDK–IPARD financing mechanisms, provide the institutional scaffolding for this agenda. Nevertheless, the current policy design remains predominantly supply-side in orientation: it focuses on expanding the availability of digital technologies rather than addressing the demand-side dynamics of smallholder adoption — the access barriers, skill gaps, and institutional deficits that determine whether the technologies are actually taken up and used effectively (FAO, 2023).

The most important lesson from EU and developing-country experience is that closing the digital divide requires integrated policy packages that address infrastructure, education, finance, and institutional support not sequentially but simultaneously (Salemink et al., 2017). Programmes that treat rural broadband as a public good, embed digital agricultural literacy into agricultural extension and training systems, and create collective technology procurement subsidies for smallholder cooperatives have consistently produced the most durable and equitable outcomes.

5. Conclusions and Policy Recommendations

This paper has argued that digital agriculture holds genuine and significant potential for rural development and green transformation — but that the realisation of this potential is not automatic. It depends critically on how the digital divide is managed. Turkey's regionally differentiated agricultural landscape maps closely onto the paper's central comparative finding: supply-side technology policies risk concentrating the benefits of digital transformation in larger and already-advantaged enterprises, while marginalising the smallholders, regionally disadvantaged producers, and women farmers who face compounding structural barriers. Five policy recommendations follow from the analysis.

(1)	Universal rural broadband infrastructure: Connectivity infrastructure — the prerequisite for all other digital interventions — must be treated as a public investment priority, with accelerated programmes targeting eastern and south-eastern Anatolia specifically.
(2)	Cooperative-centred technology access models: Subsidy and financing mechanisms should be redesigned to incentivise collective technology procurement through cooperatives, positioning them as the institutional vehicles of digital rural transformation.
(3)	Gender-responsive digital agriculture programmes: Support mechanisms for rural women producers should operate independently of land ownership conditions, incorporate flexible training modalities compatible with care work responsibilities, and prioritise women-led cooperatives for grant funding.
(4)	Alignment with EU green transformation standards: TKDK–IPARD financing mechanisms should be supplemented with a 'green component' aligned with European Green Deal criteria, explicitly linking digital precision farming support to environmental performance benchmarks.
(5)	Regional inequality monitoring system: A multidimensional digital agriculture indicator set should be established under TÜİK coordination to track the regional distribution of digital transformation outcomes, enabling policy design to be updated on the basis of disaggregated evidence.

Three avenues stand out as priorities for future research: quantitative measurement of digital divide dynamics among small-scale agricultural enterprises across Turkey's different regions; experimental evaluation of the effectiveness of gender-responsive digital farming programmes; and comparative case analysis of cooperative-centred technology access models in Turkey and comparable middle-income agricultural economies.

Author Contribution Statement

This paper is a review study and does not require ethical committee approval. The authors declare no conflicts of interest.

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FLOW PAST A SUBMERGED VANE

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ABSTRACT

This study performs a detailed numerical investigation into the complex flow mechanisms surrounding a submerged vane in an open channel with rigid bed. A total of four simulations were conducted using the software Flow-3D HYDRO. To accurately capture the transient and anisotropic nature of the turbulent flow, the Large Eddy Simulation (LES) approach with the Smagorinsky subgrid-scale model was employed. The numerical setup consisted of a 3 m long channel with a constant flow depth of 10 cm. A submerged vane, measuring 10 cm in length, 1 cm in thickness, and 3 cm in height, was positioned 1 m from the channel inlet. The primary variable under consideration was the skew angle relative to the approach flow, with tests performed at 10°, 20°, 30°, and 45°. The simulation results reveal that the skew angle is a decisive factor in determining the hydraulic performance and turbulent field of the vane. It was observed that as the skew angle increased, the vorticity at the vane tip and in the downstream region intensified significantly. Furthermore, higher skew angles led to a consistent increase in turbulence intensity, turbulent kinetic energy, and Reynolds stresses. These findings suggest that steeper angles promote more vigorous secondary currents and larger energy fluctuations.

Keywords: Submerged vanes, computational fluid dynamics, flow field

KURŞUNSUZ AG-SB LEHİM ALAŞIM SİSTEMİNİN ISIL VE ELEKTRİKSEL ÖZELLİKLERİNİN İNCELENMESİ

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ÖZET

Kurşun içeren lehim alaşımları geçmişten günümüze elektronik ve metal birleştirme teknolojilerinde önemli bir yer tutmuştur ancak kurşunun insan sağlığı ve çevre üzerindeki zararlı etkilerinin anlaşılmasıyla birlikte, bu malzemelerin kullanımına yönelik düzenlemeler artmış ve kurşunsuz lehim alaşımlarının geliştirilmesi önemli bir araştırma alanı haline gelmiştir. Lehimleme işlemleri sırasında kurşuna maruz kalmanın nörolojik bozukluklar, üreme fonksiyonlarında bozulma, hipertansiyon ve anemi gibi ciddi sağlık sorunlarıyla ilişkili olduğu bilinmektedir. Ayrıca kurşun içeren malzemelerin uygun olmayan şekilde atılması çevresel kirliliğe önemli ölçüde katkıda bulunmaktadır. Bu nedenle çevre dostu kurşunsuz lehim malzemelerinin geliştirilmesi, modern malzeme biliminin önemli araştırma alanlarından biri haline gelmiştir.

Potansiyel adaylar arasında yer alan Ag-Sb alaşımları, çevre dostu özellikleri, yüksek sıcaklık kararlılığı ve geliştirilmiş mekanik performansları nedeniyle geleneksel kurşun içeren lehim malzemelerine alternatif olarak giderek daha fazla ilgi görmektedir. Ag-Sb ikili sistemi, özellikle Ag_3Sb olmak üzere çeşitli intermetalik fazların oluşumu ile karakterizedir. Bu fazlar alaşımın sertliğini, aşınma direncini ve boyutsal kararlılığını artırırken aynı zamanda oksidasyon ve korozyon direncini de iyileştirmektedir. Bu özellikler, Ag-Sb alaşımlarını yüksek sıcaklıklarda ve sürekli mekanik yük altında güvenilir performans gerektiren uygulamalar için cazip hale getirmektedir.

Bu çalışmada Ag-Sb alaşım sistemi, termal ve elektriksel özellikleri açısından incelenmiştir. Kararlı intermetalik faz oluşumu ve yüksek sıcaklık performansı nedeniyle Ag-44 ağırlık % Sb bileşimine sahip bir alaşım seçilmiştir. Sıcaklığa bağlı ısı iletkenlik değerleri doğrusal ısı akışı sistemi kullanılarak belirlenmiş ve elde edilen deneysel verilerden ilgili iletkenlik katsayıları hesaplanmıştır. Elektriksel iletkenlik değerleri ise Wiedemann-Franz yasası kullanılarak hesaplanmıştır. Elde edilen sonuçlar, Ag-Sb alaşımlarındaki yapı-özellik ilişkileri hakkında önemli bilgiler sunmakta ve bu alaşımların yüksek performans gerektiren uygulamalar için umut verici kurşunsuz lehim malzemeleri olduğunu göstermektedir.

Anahtar Kelimeler: Isı Transferi, alaşımlar, termal özellikler, elektriksel iletkenlik

THERMAL AND ELECTRICAL PERFORMANCE EVALUATION OF LEAD-FREE AG-SB SOLDER ALLOY SYSTEM

ABSTRACT

Lead-containing solder alloys have played an important role in electronic and metal joining technologies from past to present; however, as the harmful effects of lead on human health and the environment have become increasingly recognized, regulations on their use have intensified, and the development of lead-free (Pb-free) solder alloys has become an important area of research. Exposure to lead during soldering processes is associated with severe health risks such as neurological disorders, reproductive dysfunction, hypertension, and anemia, while improper disposal of lead-containing materials contributes significantly to environmental contamination. Consequently, the development of environmentally friendly Pb-free solder materials has become an important research focus in modern materials science.

Among the potential candidates, Ag-Sb alloys have gained increasing attention as alternatives to conventional lead-containing solder materials due to their favorable environmental profile, high-temperature stability, and improved mechanical performance. The Ag-Sb binary system is characterized by the formation of intermetallic phases, particularly Ag_3Sb , which contribute to enhanced hardness, wear resistance, dimensional stability, and improved oxidation and corrosion resistance. These properties make Ag-Sb alloys attractive for applications requiring reliable performance under elevated temperatures and sustained mechanical loading.

In the present study, the Ag-Sb alloy system was investigated with regard to its thermal and electrical properties. An alloy composition of Ag-44 wt.% Sb was selected due to its stable intermetallic phase formation and promising high-temperature characteristics. Temperature-dependent thermal conductivity was determined using the linear heat-flow method, and the corresponding conductivity coefficients were calculated from the obtained experimental data. Electrical conductivity values were evaluated using the Wiedemann-Franz law. The obtained results provide important insights into the structure-property relationships in Ag-Sb alloys and demonstrate that these alloys are promising Pb-free solder materials for high-performance applications.

Keywords: Heat transfer, alloys, thermal properties, electrical conductivity

TİTANYUM DİOKSİTİN (TiO₂) NANOMALZEMENİN FUKSİN BOYASI ÜZERİNDEKİ FOTOKATALİTİK ÖZELLİKLERİNİN GELİŞTİRİLMESİ

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ÖZET

Bu çalışmada, titanyum dioksit (TiO₂) nanopartiküllerinin fuksin boyası üzerindeki fotokatalitik bozunma performansı incelenmiştir. TiO₂ nanopartikülleri 300, 500, 700 ve 900 °C sıcaklıklarda kalsine edilmiş ve kristal yapıları X-ışını kırınımı (XRD) yöntemi ile analiz edilmiştir. Sonuçlar, tüm numunelerin JCPDS 88-1175 kartı ile uyumlu anatase fazında olduğunu ve piklerin bu yapıya göre indekslendiğini göstermiştir. Bütün numunelerin yüksek kristalliğe sahip olduğu gözlemlenmiştir. Fotokatalitik deneyler UV ışık altında gerçekleştirilmiş ve boya bozunması UV-Vis spektrofotometre ile izlenmiştir. Optik bant aralıkları Kubelka–Munk yöntemi kullanılarak hesaplanmış olup, 300 ve 500 °C için 2.94 eV, 700 ve 900 °C için 2.93 eV olarak bulunmuştur. Fotokatalitik bozunma verimi 300 °C’de %23.9, 900 °C’de ise %38.3 olarak belirlenmiştir. Sonuç olarak, TiO₂ nanopartiküllerinin artan kalsinasyon sıcaklığı ile birlikte gelişmiş fotokatalitik performans sergilediği ortaya konmuştur.

Anahtar Kelimeler: TiO₂, fuksin, fotokatalitik, XRD

IMPROVEMENT OF THE PHOTOCATALYTIC PROPERTIES OF TITANIUM DIOXIDE (TiO₂) NANOMATERIALS ON FUCHSIN DYE

ABSTRACT

In this study, the photocatalytic degradation performance of titanium dioxide (TiO₂) nanoparticles on fuchsin dye was investigated. TiO₂ nanoparticles were calcined at temperatures of 300, 500, 700, and 900 °C, and their crystal structures were analyzed using X-ray diffraction (XRD). The results showed that all samples were in the anatase phase, consistent with JCPDS card 88-1175, and that the peaks were indexed according to this structure. It was observed that all samples possessed high crystallinity. Photocatalytic experiments were conducted under UV light, and dye degradation was monitored using a UV-Vis spectrophotometer. The optical band gaps were calculated using the Kubelka–Munk method

and were found to be 2.94 eV for 300 and 500 °C, and 2.93 eV for 700 and 900 °C. The photocatalytic degradation efficiency was determined to be 23.9% at 300 °C and 38.3% at 900 °C. In conclusion, it was demonstrated that TiO₂ nanoparticles exhibit improved photocatalytic performance with increasing calcination temperature.

Keywords: TiO₂, fuchsin, photocatalytic, XRD

TÜRKİYE YÜZYILI MAARİF MODELİ MATEMATİK DERSİ ÖĞRETİM PROGRAMININ SAYI HİSSİ BİLEŞENLERİ AÇISINDAN İNCELENMESİ

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ÖZET

Bu araştırmanın amacı, Türkiye Yüzyılı Maarif Modeli kapsamında geliştirilen ortaokul matematik dersi öğretim programının sayı hissi bileşenleri açısından incelenmesidir. Bu doğrultuda öğretim programında yer alan öğrenme çıktılarının sayıların anlamı, sayıların büyüklüğü, esnek işlem yapma ve tahmin etme bileşenleri ile ne ölçüde ilişkili olduğunun belirlenmesi amaçlanmıştır. Araştırma nitel araştırma yaklaşımı çerçevesinde doküman incelemesi yöntemi kullanılarak yürütülmüştür. Çalışmanın veri kaynağını Millî Eğitim Bakanlığı tarafından yayımlanan Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programı oluşturmaktadır. Araştırma kapsamında programda yer alan 5–8. sınıf düzeylerindeki toplam 100 öğrenme çıktısı incelenmiştir. Veri analizi sürecinde öğrenme çıktıları, Gülbağcı-Dede (2015) tarafından ortaya konulan sayı hissi temel bileşenleri çerçevesinde betimsel analiz yöntemi ile analiz edilmiştir. Araştırma bulgularına göre öğretim programında yer alan 100 öğrenme çıktısından 45'inin (%45) sayı hissi ile ilişkili olduğu belirlenmiştir. Sayı hissi bileşenleri açısından incelendiğinde öğrenme çıktılarının en fazla sayıların anlamı ve tahmin etme bileşenlerinde yoğunlaştığı görülmektedir. Ayrıca sayı hissi ile ilişkili öğrenme çıktılarının büyük ölçüde sayılar ve nicelikler teması içerisinde yer aldığı belirlenmiştir. Araştırma sonuçları, Türkiye Yüzyılı Maarif Modeli ortaokul matematik öğretim programının sayı hissi gelişimini destekleyebilecek öğrenme çıktıları içerdiğini; ancak sayı hissi bileşenlerinin program içerisinde dengeli bir dağılım göstermediğini ortaya koymaktadır. Bu araştırmadaki değerlendirmeler, öğretim programında yer alan öğrenme çıktıları ve süreç bileşenleri esas alınarak yapılmıştır. Öğretim programında sayı hissiyle doğrudan ilişkilendirilmeyen bir öğrenme çıktısı, uygun öğrenme ortamlarında ve kavramsal temelli bir öğretim anlayışıyla sunulduğunda sayı hissi gelişimine katkı sağlayabilir. Bu nedenle öğretim süreçlerinin de sayı hissi bileşenlerine yönelik incelenmesini içeren çalışmalar yapılabilir.

Anahtar kelimeler: Sayı hissi, matematik öğretim programı, Türkiye Yüzyılı Maarif Modeli, matematik eğitimi

AN ANALYSIS OF THE NUMBER SENSE COMPONENTS OF THE TURKEY CENTURY EDUCATION MODEL MATHEMATICS CURRICULUM

ABSTRACT

The aim of this study is to examine the secondary school mathematics curriculum developed within the scope of the Türkiye Century Education Model in terms of number sense components. In this context, the study aims to determine the extent to which the learning outcomes included in the curriculum are associated with the components of number sense, namely meaning of numbers, magnitude of numbers, flexible computation, and estimation. The research was conducted using the document analysis method within the framework of a qualitative research approach. The data source of the study consists of the secondary school mathematics curriculum of the Türkiye Century Education Model published by the Ministry of National Education. Within the scope of the research, a total of 100 learning outcomes at the 5th–8th grade levels included in the curriculum were examined. During the data analysis process, the learning outcomes were analyzed through descriptive analysis based on the number sense components proposed by Gülbağcı-Dede (2015). The findings revealed that 45 of the 100 learning outcomes (45%) included in the curriculum were related to number sense. When examined in terms of number sense components, it was observed that the learning outcomes were mostly concentrated in the components of meaning of numbers and estimation. In addition, it was determined that learning outcomes related to number sense were largely included in the theme of numbers and quantities. The results of the study indicate that the secondary school mathematics curriculum developed within the scope of the Türkiye Century Education Model includes learning outcomes that can support the development of number sense; however, the components of number sense are not distributed in a balanced manner throughout the curriculum. In this study, the evaluations were carried out based on the learning outcomes and process components included in the curriculum. A learning outcome that is not directly associated with number sense in the curriculum may contribute to the development of number sense when presented through appropriate learning environments and a conceptually oriented teaching approach. Therefore, further studies examining instructional processes in relation to number sense components are recommended.

Keywords: Number sense, mathematics curriculum, Turkish Century Education Model, mathematics education

GİRİŞ

Matematik eğitiminin temel hedeflerinden biri, öğrencilerin yalnızca işlemsel yeterlik kazanmaları değil; aynı zamanda sayılarla anlamlı ilişkiler kurabilen, tahmin yürütebilen, esnek düşünebilen ve matematiksel düşüncelerini günlük yaşam bağlamlarında kullanabilen bireyler olarak yetişmeleridir. Bu doğrultuda matematiksel yeterliğin önemli belirleyicilerinden biri olarak öne çıkan kavramlardan biri sayı hissidir. Sayı hissi, bireyin sayıları yalnızca sembolik yapılar olarak değil, anlamlı nicelikler olarak algılayabilmesini; sayılar ve işlemler arasında sezgisel ve mantıklı ilişkiler kurabilmesini ifade eden çok boyutlu bir bilişsel yapı olarak tanımlanmaktadır (McIntosh, Reys & Reys, 1992; Sowder, 1992).

Alanyazında sayı hissine yönelik farklı tanımların bulunduğu görülmektedir. Hope (1989), sayı hissini sayısal durumlara ilişkin mantıklı tahminlerde bulunabilme ve uygun hesaplama yollarını seçebilme yeteneği olarak ele alırken; Howden (1989), sayılar ve aralarındaki ilişkiler hakkında sezgisel bir anlayış geliştirme becerisi olarak tanımlamaktadır. Berch'e (2005) göre ise sayı hissi, bireyin sayıların anlamına ilişkin geliştirdiği duyuşsal farkındalıkla ilgilidir. Bu tanımlar ortak bir noktada birleşerek sayı hissini kurallara dayalı mekanik işlem yapma becerisinin ötesinde, akıl yürütmeye dayalı esnek düşünmeyi içerdiğini göstermektedir.

Sayı hissi; sayıların büyüklüğünü kavrayabilme, zihinden işlem yapabilme, tahmin yürütebilme, işlemlerde esnek stratejiler kullanabilme ve elde edilen sonuçların akla yatkınlığını değerlendirebilme gibi birden fazla bilişsel süreci kapsamaktadır (Reys et al., 1999; Yang, 2005). Araştırmalar, gelişmiş sayı hissine sahip öğrencilerin problem çözme süreçlerinde daha etkili stratejiler kullandıklarını, matematiksel ilişkilendirme becerilerinin daha güçlü olduğunu ve üst düzey düşünme süreçlerinde daha başarılı olduklarını ortaya koymaktadır (Verschaffel, Greer & De Corte, 2007). Bu yönüyle sayı hissi, matematiksel anlamının derinleşmesinde ve matematiğin günlük yaşamla ilişkilendirilmesinde kritik bir rol oynamaktadır.

Sayı hissi kavramının tanımlanmasına paralel olarak, bu yapıyı oluşturan bileşenlere ilişkin çeşitli sınıflandırmalar geliştirilmiştir. Greeno (1991) sayı hissini esnek zihinsel hesaplama, sayısal tahmin ve nicel yargılama boyutlarıyla ele alırken; Markovits ve Sowder (1994) sayı büyüklüğünü anlama, zihinsel hesaplama ve tahmini öne çıkarmıştır. Reys ve arkadaşları (1999) ise sayı hissini daha kapsamlı biçimde ele alarak sayıların anlamını kavrama, eşdeğer temsilleri kullanma, işlemlerin etkilerini anlama ve esnek hesaplama stratejileri geliştirme gibi çoklu bileşenlerden söz etmiştir. Yang (1995) ise bu yapıya sayıları parçalama ve yeniden yapılandırma ile referans noktası kullanımını da dahil etmiştir. Ancak yapılan çalışmalar, sayı

hissinin bileşenlerine ilişkin ortak bir terminolojinin henüz tam olarak oluşmadığını ve farklı araştırmacıların benzer becerileri farklı adlandırmalarla ele aldığını göstermektedir (Gülbağcı-Dede & Şengül, 2016).

Bu durum, sayı hissini ölçülebilir ve öğretilebilir boyutlarının belirlenmesini önemli hale getirmiştir. Nitekim Gülbağcı-Dede (2015), sayı hissini ölçülebilir temel bileşenler çerçevesinde ele alarak; sayıların anlamını kavrama, sayı büyüklüğünü değerlendirme, esnek işlem yapma ve tahmin becerisi gibi boyutların bu yapının temel göstergeleri olduğunu ortaya koymuştur. Bu bileşenlerden ilki olan sayıların anlamı bileşeni, öğrencinin sayıları yalnızca sembolik ifadeler olarak değil; farklı temsilleri, basamak değerleri ve sayılar arası ilişkiler bağlamında kavrayabilmesini ifade eder. Bu bileşen; sayıları parçalayabilme ve yeniden oluşturabilme, eşdeğer gösterimlerini fark edebilme ve onluk sistem yapısını anlayabilme gibi becerileri kapsar. Başka bir ifadeyle, öğrencinin sayının yapısını ve temsil ediliş biçimlerini anlamlandırarak sayılarla esnek biçimde düşünebilmesini içerir. İkinci bileşen olan sayıların büyüklüğü bileşeni; sayıları sıralayabilme, aralarındaki büyüklük farkını anlayabilme ve sayıların birbirine olan uzaklığını değerlendirebilme becerilerini kapsar. Kısaca, öğrencinin sayıların niceliksel değerini sezgisel ve kavramsal olarak yorumlayabilmesini içerir. Üçüncü bileşen olan esnek işlem yapma ve sonucun akla yatkınlığını değerlendirme bileşeni, öğrencilerin işlemleri yalnızca standart algoritmalarla değil; zihinden işlem, tahmin ve yuvarlama gibi stratejiler kullanarak gerçekleştirebilmesini ve elde ettiği sonucun mantıklı olup olmadığını sorgulayabilmesini ifade eder. Kısaca, sayı ve işlem bilgisini kullanarak esnek çözümler üretebilme ve sonucu akıl yürütme yoluyla değerlendirebilme becerisini kapsar. Son bileşen olan tahmin etme bileşeni, sayma veya ölçme yapmadan bir niceliğin büyüklüğü hakkında hızlı ve mantıklı çıkarımlarda bulunabilme becerisini ifade eder. Kısaca, öğrencinin yaklaşık değerleri akıl yürüterek belirleyebilmesini ve sayısal durumları sezgisel olarak değerlendirebilmesini kapsar.

Öğrencilerin sayı hissi geliştirme süreçlerinde öğretim programları önemli bir belirleyici rol üstlenmektedir. Programlarda yer alan kazanımların niteliği, sunulan öğrenme deneyimleri ve önerilen öğretim yaklaşımları; öğrencilerin matematiği kavramsal bir anlayışla mı yoksa işlemsel bir düzeyde mi öğreneceklerini doğrudan etkilemektedir (Reys et al., 1999). Bu nedenle matematik öğretim programlarının sayı hissini hangi boyutlarda ve ne ölçüde desteklediğinin ortaya konulması, matematiksel öğrenmenin niteliğini değerlendirmek açısından önem taşımaktadır. Nitekim alanyazında, sayı hissini öğretim programlarında yer almasının gerekliliği pek çok araştırma ve raporda vurgulanmaktadır (Anghileri, 2006;

Kilpatrick, Swafford & Findell, 2001; Sowder & Schappelle, 1989; Verschaffel, Greer & De Corte, 2007). Umay, Akkuş ve Paksu (2006), sayı hissini önemi NCTM tarafından vurgulanmış olmasına rağmen ülkemizdeki öğretim programında sayı hissini oluşturma anlamında kazanım ya da etkinlik bulunmadığını ifade etmiştir.

Cumhuriyet'in ilanından günümüze kadar geçen süreçte ortaokul matematik dersi öğretim programı farklı dönemlerde çeşitli revizyonlara uğramıştır. 1926 yılından başlayarak 1931, 1938, 1949, 1977, 1990, 1998, 2005, 2013, 2017 (2018'de güncellenmiştir) ve son olarak 2024 yıllarında program değişiklikleri gerçekleştirilmiştir. Türkiye'de öğretim programlarının tarihsel süreç içerisinde sıklıkla güncellenmesi, değişen toplumsal, bilimsel ve pedagojik ihtiyaçlara uyum sağlama çabasının bir yansıması olarak değerlendirilebilir. Bu kapsamda 2024 yılında, diğer kademelere ait programlarla birlikte ortaokul matematik dersi öğretim programı da Türkiye Yüzyılı Maarif Modeli [TYMM] çerçevesinde yeniden yapılandırılmıştır (Millî Eğitim Bakanlığı [MEB], 2024).

Türkiye Yüzyılı Maarif Modeli ile güncellenen ortaokul matematik dersi öğretim programında, öğrencilerin yalnızca bilgiyi edinmeleri değil; aynı zamanda çağın gerektirdiği becerilerle donatılmaları hedeflenmektedir. Programda matematiksel öğrenme süreçlerini destekleyen kavramsal becerilerin ve matematiğe özgü düşünme becerilerinin ön plana çıkarıldığı; bu becerilerin sosyal-duygusal öğrenme, eğilimler ve okuryazarlık becerileriyle bütüncül bir anlayış içinde geliştirilmesinin amaçlandığı ifade edilmektedir (MEB, 2024). Bu yönüyle program, bilgi aktarımından çok beceri temelli ve bütünsel bir öğrenme yaklaşımını benimsemektedir.

2024 yılında yürürlüğe giren yeni öğretim programlarının bilimsel açıdan incelenmesi, programın kuramsal temellerinin ve uygulamaya dönük yönelimlerinin değerlendirilmesi bakımından önem taşımaktadır. Programın henüz yeni olması nedeniyle bu alanda yapılan çalışmaların sınırlı olduğu görülmektedir. 2024 yılında yürürlüğe giren Türkiye Yüzyılı Maarif Modeli'ne ilişkin çalışmalar incelendiğinde, programın farklı kuramsal ve uygulama boyutları çerçevesinde ele alındığı görülmektedir. Programın bilişsel yönelimine odaklanan araştırmalarda, öğrenme çıktılarının ve süreç bileşenlerinin çeşitli taksonomik çerçeveler doğrultusunda analiz edildiği dikkat çekmektedir. Bu kapsamda öğrenme çıktılarının Bloom taksonomisi (Karataş-Tekin, 2024) ve SOLO taksonomisi ile bilişsel istem düzeyleri (Cihan & Doruk, 2024) açısından değerlendirildiği; ayrıca matematik alan becerilerinin yatay ve dikey bağlamda çok yönlü analiz edildiği çalışmaların bulunduğu görülmektedir (Göçer & Kuzu, 2025). Programın 21. yüzyıl becerileri perspektifiyle incelendiği (Asker-Dağdeviren, 2024;

Yıldırım & Çalışkan, 2024), sosyal-duygusal öğrenme boyutunun ele alındığı (Uzun, 2025) ve erdem-değer-eylem çerçevesi ile değerler eğitimi yaklaşımı bağlamında değerlendirildiği çalışmalar (Arslan, 2025; Taşkın, 2025) da alanyazında yer almaktadır. Bunun yanında programın ontolojik, epistemolojik ve aksiyolojik temelleri açısından incelendiği kuramsal analizler de bulunmaktadır (Arslankara & Arslankara, 2024).

Programın uygulamaya dönük boyutunu ele alan araştırmalarda ise öğretmen ve akademisyen görüşlerine dayalı değerlendirmelerin öne çıktığı görülmektedir. Öğretmen görüşleri doğrultusunda programın genel yapısının ve uygulama sürecinin incelendiği çalışmalar (Koç, 2025; Sağbaş, 2025; Öztürk, Akıncı & Beldağ, 2025), matematik öğretmenlerinin programa ilişkin metaforik algılarının analiz edildiği araştırmalar (Yılmaz vd., 2025) ve uygulama sürecinde karşılaşılan sorunların ele alındığı çalışmalar (Yılmaz & Özdemir, 2025) bu kapsamda değerlendirilebilir. Ayrıca ölçme ve değerlendirme yaklaşımının çeşitli değişkenler açısından incelendiği (Aşiret & Özenir, 2025; Güneş, Dursun & Alcı, 2025), farklılaştırılmış öğretim perspektifiyle programın değerlendirildiği (Pala, 2025) ve matematik tarihi bağlamında analiz edildiği araştırmalar (Çıkar & Gökçek, 2025) da dikkat çekmektedir.

Bununla birlikte Türkiye Yüzyılı Maarif Modeli'nin önceki programlarla karşılaştırmalı olarak incelendiği çalışmalar da bulunmaktadır. 2018 ve 2024 matematik öğretim programlarının çeşitli boyutlar açısından karşılaştırıldığı araştırmalar (Kuzu, Toptaş & Göçer, 2024; Er & Özyurt, 2025) programın yapısal dönüşümünü ortaya koymaya yönelik önemli katkılar sunmaktadır. Ayrıca belirli temalar üzerinden yapılan analizler, özellikle geometri öğrenme alanı bağlamında öğretmen görüşlerine dayalı incelemelerle desteklenmiştir (Daştan & Aydın, 2025; Uysal, 2025).

Genel olarak değerlendirildiğinde, Türkiye Yüzyılı Maarif Modeli'nin bilişsel düzeyler, değerler eğitimi, ölçme-değerlendirme yaklaşımları, 21. yüzyıl becerileri, program felsefesi ve öğretmen görüşleri gibi farklı boyutlar çerçevesinde ele alındığı görülmektedir. Ancak alanyazında programın matematiksel düşünmenin temel yapı taşlarından biri olan sayı hissi bağlamında sistematik biçimde incelendiğine dair çalışmaya rastlanmamıştır. Bu durum, Türkiye yüzyılı maarif modeli ortaokul matematik dersi öğretim programının sayı hissi bileşenleri açısından analiz edilmesini gerekli ve özgün bir araştırma alanı olarak ortaya koymaktadır.

Sayı hissi ve öğretim programları arasındaki ilişkiyi ele alan çalışmalar incelendiğinde, Türkiye'de bu alanda gerçekleştirilen araştırmaların sınırlı olduğu görülmektedir. Program düzeyinde yapılan ilk kapsamlı çalışmalardan biri Harç (2010) tarafından yüksek lisans tezi

kapsamında gerçekleştirilmiştir. Bu çalışmada Amerika, İngiltere, Türkiye ve New Jersey’de uygulanan 1–6. sınıf matematik öğretim programları sayı hissi bileşenleri açısından karşılaştırmalı olarak incelenmiştir. Araştırma bulguları, incelenen programlarda sayı hissi kavramına doğrudan yer verilmemekle birlikte, sayı hissini alt bileşenlerine karşılık gelen kazanım ve ifadelerle yer verildiğini ortaya koymuştur. Türkiye bağlamında ise 1–6. sınıf düzeyinde toplam 25 kazanımın sayı hissi bileşenleriyle ilişkili olduğu belirlenmiştir (Harç, 2010).

Benzer biçimde Gülbağcı-Dede (2015), doktora tez çalışmasında 1–11. sınıflar arasındaki matematik öğretim programlarını sayı duygusu bileşenleri çerçevesinde incelemiştir. Çalışmada 1–8. sınıflar için 2009 yılı programı, 9–11. sınıflar için ise 2013 yılı programı analiz edilmiştir. Bulgular, 2009 yılı ortaokul matematik öğretim programının genel amaçlarında zihinden işlem, tahmin, ilişki kurma ve strateji geliştirme gibi sayı duygusuyla bağlantılı becerilere vurgu yapıldığını; ancak kazanım düzeyinde sayı duygusuna açık bir kavramsal çerçeveye yer verilmediğini göstermiştir (Gülbağcı-Dede, 2015; Harç, 2010).

Uluslararası standartlarla karşılaştırmalı değerlendirmelerde alanyazının da yer almaktadır. Kılıç (2011), NCTM ilke ve standartları ile Türkiye’de uygulanan ilköğretim matematik dersi öğretim programını sayı hissi bağlamında incelemiştir; NCTM dokümanlarında sayı hissini açık ve sistematik biçimde vurgulandığını, buna karşın Türkiye’deki programda sayı hissi ve bileşenlerinin doğrudan ele alınmadığını ortaya koymuştur. Bu bulgu, programlarda sayı hissine yönelik yaklaşım farklılıklarını göstermesi bakımından önemlidir.

Son yıllarda yürürlüğe giren programlara yönelik analizler de dikkat çekmektedir. Birgin ve Peker (2019) 2018 matematik dersi öğretim programını sayı duygusu bileşenleri açısından incelemiştir; Çetin ve Öztürk (2020) ise ilköğretim matematik öğretim programını sayı duygusunun temel bileşenleri doğrultusunda değerlendirmiştir. Çekirdekçi ve Yorulmaz (2021) tarafından gerçekleştirilen çalışmada ise 2009, 2015 ve 2018 ilköğretim matematik öğretim programları “Sayılar ve İşlemler” ile “Ölçme” öğrenme alanları özelinde sayı hissi bileşenlerine göre karşılaştırılmıştır. Ortaokul düzeyinde yapılan analizlerde de benzer bir eğilim görülmektedir. Acar ve Peker (2021) 2018 ortaokul matematik dersi öğretim programını sayı hissi bileşenleri açısından incelerken; Karabey ve arkadaşları (2019) 2009, 2013 ve 2017 yıllarına ait ortaokul matematik öğretim programlarını sayı duygusu bağlamında karşılaştırmalı olarak değerlendirmiştir.

Genel olarak değerlendirildiğinde, Türkiye’de matematik öğretim programlarının sayı hissi bileşenleri açısından incelenmesine yönelik çalışmaların sayısının sınırlı olduğu; mevcut

çalışmaların ise belirli program yılları veya öğrenme alanları ile sınırlı kaldığı görülmektedir. Özellikle yeni yürürlüğe giren öğretim programlarının sayı hissi bağlamında analiz edilmesi, alanyazındaki bu boşluğun doldurulması açısından önem taşımaktadır. Türkiye’de 2024 yılı itibarıyla yürürlüğe giren Türkiye Yüzyılı Maarif Modeli, beceri temelli ve bütüncül öğrenme anlayışını merkeze alan bir yapı sunmaktadır. Model, öğrencilerin bilgiyi yalnızca edinmelerini değil; anlamlandırmalarını, ilişkilendirmelerini ve gerçek yaşam bağlamlarında kullanabilmelerini hedeflemektedir. Bu yönüyle Türkiye Yüzyılı Maarif Modeli’nin matematik öğretiminde sayı hissini destekleyici bir potansiyele sahip olduğu değerlendirilmektedir. Ancak yeni öğretim programlarının bu tür bilişsel becerileri nasıl yapılandırdığına ilişkin bilimsel incelemeler henüz sınırlıdır.

Bu bağlamda, Türkiye Yüzyılı Maarif Modeli Matematik Dersi Öğretim Programı’nın sayı hissi bileşenleri açısından incelenmesi, hem programın matematiksel yöneliminin ortaya konulması hem de uygulamaya yönelik çıkarımlar sunulması açısından önemli görülmektedir. Programın sayı hissi bağlamında değerlendirilmesi, ülkemizde bu beceriye verilen önemin anlaşılmasına katkı sağlayabileceği gibi, gelecekte yapılacak program geliştirme çalışmalarına da ışık tutabilecektir. Bu doğrultuda araştırmanın temel problemi “Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında sayı hissi ve sayı hissi bileşenlerinin hangi düzeyde yer aldığı belirlenmesidir.” Araştırmanın alt problemleri ise;

1. Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında sınıf düzeylerine göre sayı hissi ve bileşenlerine ne düzeyde yer verilmektedir?
2. Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında temalara göre sayı hissi ve bileşenlerine ne düzeyde yer verilmektedir?

Araştırmanın Amacı

Bu araştırmanın amacı, Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programının sayı hissi bileşenleri açısından incelenmesidir. Bu doğrultuda çalışmada, programda yer alan öğrenme çıktılarının sayıların anlamı, sayıların büyüklüğü, esnek işlem yapma ve sonucun akla yatkınlığını değerlendirme ile tahmin etme gibi sayı hissi bileşenleriyle ne ölçüde ilişkili olduğunun belirlenmesi hedeflenmektedir.

Araştırma kapsamında, öğretim programının sayı hissi gelişimini destekleme potansiyeli sınıf düzeyleri ve temalar bağlamında analiz edilerek programın matematiksel düşünmenin kavramsal yönünü ne ölçüde desteklediği ortaya konulmaya çalışılmaktadır. Bu yönüyle çalışma, Türkiye Yüzyılı Maarif Modeli matematik öğretim programının sayı hissi

bağlamındaki yapısını ortaya koymayı ve program geliştirme süreçlerine veri sunmayı amaçlamaktadır.

YÖNTEM

Bu bölümde araştırmanın modeli, veri kaynağı, veri toplama süreci ve veri analizi ayrıntılı biçimde açıklanmıştır.

Araştırma Modeli

Bu araştırma, nitel araştırma yaklaşımı çerçevesinde yürütülmüş olup veri toplama yöntemi olarak doküman incelemesi kullanılmıştır. Nitel araştırmalar, incelenen olguyu doğal bağlamı içerisinde anlamlandırmayı, yorumlamayı ve derinlemesine çözümlemeyi amaçlayan bir araştırma yaklaşımıdır (Guba & Lincoln, 1994; Klenke, 2016). Bu tür araştırmalarda temel amaç, belirli bir durumu açıklamak ya da genelleme yapmak değil; incelenen olgunun yapısını, anlamını ve bağlamsal özelliklerini ortaya koymaktır.

Çalışma, Merriam'ın (1998, 2009) tanımladığı temel nitel araştırma deseni doğrultusunda yapılandırılmıştır. Temel nitel araştırmalar, araştırmacının belirli bir durumu ya da dokümanı yorumlayıcı bir bakış açısıyla incelemesini ve elde edilen verileri anlamlandırmasını esas alır. Bu çalışmada da Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Dersi Öğretim Programı'nın sayı hissi ve sayı hissi bileşenleri açısından analiz edilmesi amaçlandığından, yorumlayıcı nitel yaklaşım benimsenmiştir.

Araştırmada veri kaynağı olarak Millî Eğitim Bakanlığı tarafından 2024 yılında yayımlanan Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Dersi Öğretim Programı kullanılmıştır. Doküman incelemesi, araştırılması hedeflenen olguya ilişkin yazılı materyallerin sistematik biçimde incelenmesini ve çözümlenmesini içeren bir yöntemdir (Yıldırım & Şimşek, 2018). Eğitim araştırmalarında öğretim programlarının yapısal özelliklerini, içerik yönelimlerini ve kuramsal çerçevesini analiz etmeye yönelik çalışmalarda doküman incelemesi sıklıkla tercih edilmektedir. Doküman incelemesi yöntemi, araştırmacıya veriye doğrudan erişim sağlama, materyali bağlamı içerisinde değerlendirme ve sistematik analiz yapma imkânı sunmaktadır (Creswell, 2014). Ayrıca bu yöntem, gözlem veya görüşme gibi veri toplama süreçlerine ihtiyaç duyulmaksızın mevcut resmî belgeler üzerinden derinlemesine inceleme yapılmasına olanak tanımaktadır (Yıldırım & Şimşek, 2018). Bu çalışmada öğretim programında yer alan öğrenme çıktıları ve temaları; sayı hissi bileşenleri çerçevesinde analiz edilerek değerlendirilmiştir.

Bu araştırma, Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Dersi Öğretim Programı'nın sayı hissi bileşenleri doğrultusunda incelenmesine yönelik betimleyici ve yorumlayıcı nitel bir doküman analizi çalışmasıdır.

Veri Kaynağı

Bu araştırmanın veri kaynağını, Millî Eğitim Bakanlığı tarafından 2024 yılında yayımlanan ve 2024–2025 eğitim öğretim yılından itibaren kademeli olarak uygulanmaya başlanan Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Dersi Öğretim Programı oluşturmaktadır. Araştırmada incelenen öğretim programı, kamuya açık ve resmî bir belge niteliği taşıdığından etik kurul izni gerektirmemektedir. Doküman incelemesi yöntemi kapsamında kullanılan bu program, araştırmanın temel veri setini oluşturmaktadır. Resmî öğretim programları, eğitim sisteminin kuramsal yönelimlerini, içerik önceliklerini ve beceri temelli hedeflerini yansıtan temel dokümanlar olarak değerlendirilmektedir. Bu nedenle program dokümanları, matematiksel düşünmenin belirli bileşenleri açısından sistematik analiz yapmaya olanak sağlayan güvenilir veri kaynaklarıdır (Lincoln & Guba, 1985).

Veri Toplama Süreci

Araştırmada veri toplama süreci sistematik ve aşamalı bir biçimde yürütülmüştür. Süreç, kuramsal çerçevenin oluşturulması, öğrenim çıktılarının incelenmesi ve kodlama aşamalarını içermektedir.

Birinci aşamada, sayı hissine ilişkin alanyazın kapsamlı biçimde incelenmiş ve sayı hissi bileşenlerine yönelik kuramsal bir çerçeve oluşturulmuştur. Bu doğrultuda Gülbağcı-Dede'nin (2015), çalışmasından yararlanılarak analiz sürecinde kullanılacak kod listesi geliştirilmiştir. Kod listesi; sayıların anlamını, sayı büyüklüğü, esnek işlem yapma ve tahmin etme bileşenlerini içerecek şekilde yapılandırılmıştır.

İkinci aşamada, Millî Eğitim Bakanlığı tarafından yayımlanan Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Dersi Öğretim Programı'nda yer alan 5-8. sınıf düzeylerindeki tüm matematik öğrenme çıktıları sınıf düzeylerine göre ayrı ayrı listelenmiştir. Program dokümanına Millî Eğitim Bakanlığı'nın resmî internet sitesi üzerinden erişilmiş ve dokümanın özgünlüğü ile resmî niteliği kontrol edilmiştir. Kamuya açık resmî bir belge olması nedeniyle doküman doğrudan veri kaynağı olarak kullanılmıştır.

Üçüncü aşamada, programda yer alan her bir öğrenme çıktısı, içerdiği bilişsel süreçler ve matematiksel yönelimler dikkate alınarak sayı hissi bileşenleri ile ilişkilendirilmiştir. Kodlama sürecinde bir öğrenme çıktısının birden fazla sayı hissi bileşeniyle ilişkili olduğu durumlarda çoklu kodlama yapılmıştır. Bu yaklaşım, öğrenme çıktılarının yalnızca tek bir boyuta indirgenmesini önleyerek daha kapsamlı bir analiz yapılmasına olanak sağlamıştır.

Veri toplama süreci, doküman analizine ilişkin alanyazında belirtilen aşamalar doğrultusunda yürütülmüştür (Forster, 1995). Bu kapsamda dokümanlara erişim sağlanmış, dokümanların

resmî ve özgün olduğu doğrulanmış, dokümanlar sistematik biçimde incelenmiş ve analiz sürecine hazır hâle getirilmiştir. Elde edilen veriler, araştırmanın problem ve alt problemleri doğrultusunda düzenlenmiş ve analiz aşamasına aktarılmıştır.

Veri Analizi

Araştırmada elde edilen veriler betimsel analiz yöntemiyle çözümlenmiştir. Betimsel analiz, önceden belirlenen kuramsal çerçeve doğrultusunda verilerin sistematik biçimde düzenlenmesi, özetlenmesi ve yorumlanmasını içeren bir nitel veri analiz tekniğidir (Yıldırım & Şimşek, 2018). Bu yaklaşımda amaç, elde edilen bulguları belirli temalar altında yapılandırarak okuyucuya düzenli ve anlaşılır bir biçimde sunmaktır.

Bu çalışmada analiz çerçevesi, Gülbağcı (2015) tarafından ortaya konulan sayı hissi temel bileşenleri esas alınarak oluşturulmuştur. Söz konusu bileşenler; sayıların anlamı, sayıların büyüklüğü, esnek işlem yapma ve tahmin etme boyutlarını kapsamaktadır. Bu çerçevenin tercih edilmesinin temel nedeni, sayı hissini ölçülebilir ve analiz edilebilir alt boyutlara ayrılmış olması ve program incelemelerinde sistematik kodlama yapılmasına olanak sağlamasıdır.

Araştırmada özellikle vurgulanması gereken bir husus, bir öğrenim çıktısının sayı hissi ile ilişkili olup olmamasının yalnızca metinsel ifadeye bağlı olmadığıdır. Öğrenme çıktısının öğrencilerle nasıl ele alındığı, hangi öğretim stratejileriyle sunulduğu ve öğretmenin konuya ilişkin pedagojik yaklaşımı, sayı hissini geliştirmede belirleyici olabilmektedir (Gülbağcı-Dede, 2015). Bu nedenle öğretim programında sayı hissiyle doğrudan ilişkilendirilmeyen bir öğrenme çıktısı, uygun öğrenme ortamlarında ve kavramsal temelli bir öğretim anlayışıyla sunulduğunda sayı hissi gelişimine katkı sağlayabilir. Bununla birlikte bu araştırmada değerlendirmeler, öğretim programında yer alan öğrenme çıktılarının resmî ifadeleri, açıklamaları ve örnekleri esas alınarak yapılmıştır. Analiz sürecinde program metninde açıkça yer verilen yönelimler dikkate alınmış, öğretim sürecine ilişkin olası uygulama farklılıkları kapsam dışında tutulmuştur.

Analiz sürecinde öncelikle öğretim programında yer alan öğrenim çıktıları sınıf düzeylerine göre düzenlenmiş, ardından her bir öğrenim çıktısı belirlenen sayı hissi bileşenleri doğrultusunda incelenmiştir. Öğrenim çıktısının ifade ettiği bilişsel süreçler ve matematiksel yönelimler dikkate alınarak ilgili bileşenlerle eşleştirme yapılmıştır. Bir öğrenme çıktısının birden fazla sayı hissi boyutunu içermesi durumunda çoklu kodlama yapılmış ve bu durum analiz tablolarında ayrıca belirtilmiştir.

Öğretim programında bulunan öğrenme çıktıları sayı hissi bileşenlere göre incelenirken; öğrenim çıktısı ile süreç bileşenleri de dikkate alınmıştır. Örnek bir analiz Tablo 1’de verilmiştir.

Tablo 1. Araştırma İle İlgili Örnek Analiz Tablosu

Sınıf Düzeyi	Tema	Öğrenme Çıktısı	Analiz Süreci
5.sınıf	İşlemlerle Cebirsel Düşünme	<p>MAT.5.2.1. Eşitliğin korunumuna ve işlem özelliklerine yönelik çıkarım yapabilme</p> <p>a) Eşitliğin korunumuna, doğal sayılarla toplama ve çarpma işlemlerinin değişme, birleşme; çarpmanın toplama ve çıkarma işlemleri üzerine dağılma özelliklerine yönelik varsayımlarda bulunur.</p> <p>b) İncelediği örnekler üzerinden varsayımına yönelik genellemeleri belirler.</p> <p>c) Elde ettiği genellemelerin varsayımını karşılayıp karşılamadığını çeşitli örnekler üzerinden sınar.</p> <p>ç) Varsayımı ile ilgili ulaştığı sonuca yönelik doğrulayabileceği matematiksel bir önermeyi sözel ve sembolik temsil ile sunar.</p> <p>d) Sunduğu önermenin katkısına yönelik gerekçe sunar.</p>	<p>Öğrenme çıktısında eşitliğin korunumu ve işlem özellikleri üzerinden varsayım oluşturma, genelleme yapma ve elde edilen sonuçları sınıma süreçleri yer almaktadır. İşlemlerin yapısını kavrama ve bu yapıya dayalı çıkarım yapma, sayı hissini “esnek işlem yapma ve sonucun akla yatkınlığını değerlendirme” bileşeni ile ilişkilidir. Bu nedenle ilgili öğrenme çıktısı söz konusu bileşen kapsamında değerlendirilmiştir.</p>
6.Sınıf	Sayılar ve Nicelikler	<p>MAT.6.1.5. Gerçek yaşam durumlarında ondalık gösterimlerin basamak değerlerini kesirlerden yararlanarak yorumlayabilme</p> <p>a) Ondalık gösterimlerin basamak değerlerini inceler.</p> <p>b)Ondalık gösterimlerin basamak değerlerini paydası 10, 100 ve 1000 olan kesirlerin toplamlarını kullanarak yeniden ifade eder.</p> <p>c)Ondalık gösterimlerin basamak değerlerini kendi cümleleriyle açıklar.</p>	<p>Öğrenme çıktısında ondalık gösterimlerin basamak değerlerinin kesirler aracılığıyla yeniden ifade edilmesi ve açıklanması vurgulanmaktadır. Bu durum, sayıların onluk sistem yapısını kavrama, basamak değerini anlama ve sayının eşdeğer temsillerini kullanma becerilerini içermektedir. Söz konusu bilişsel süreçler sayı hissini “sayıların anlamı” bileşeni kapsamında değerlendirildiğinden, ilgili öğrenme çıktısı bu bileşen altında kodlanmıştır.</p>
7.Sınıf	Veriden Olasılığa	<p>MAT.7.7.2. Aynı deneye ait olayların eşit olasılıklı olma durumlarını değerlendirebilme</p> <p>a) Eşit olasılıklı olan ve eşit olasılıklı olmayan olaylara ilişkin ölçüt belirler.</p> <p>b) Olayların eşit olasılıklı olma veya olmama olasılığına ilişkin hesaplama yapar.</p> <p>c) Hesaplama sonuçlarını belirlediği ölçütlerle karşılaştırır.</p> <p>ç) Karşılaştırmalarına ilişkin yargıda bulunur.</p>	<p>Öğrenme çıktısında olayların eşit olasılıklı olma durumuna ilişkin hesaplama yapılması ve elde edilen sonuçların belirlenen ölçütlerle karşılaştırılması vurgulanmaktadır. Olasılık değerlerinin karşılaştırılması, niceliksel büyüklük değerlendirmesi gerektirdiğinden bu öğrenme çıktısı “sayıların büyüklüğü” bileşeni kapsamında ele alınmıştır. Ayrıca hesaplama sonuçlarına ilişkin yargıda bulunma süreci, sonucun değerlendirilmesini içerdiği için “esnek işlem yapma ve sonucun akla yatkınlığını değerlendirme” bileşeni ile de ilişkilendirilmiştir. Bu nedenle</p>

			öğrenme çıktısı çoklu kodlama kapsamında değerlendirilmiştir.
7.Sınıf	Geometrik Şekiller	MAT.7.5.1. Matematiksel araç ve teknolojiden yararlanarak üçgende kenarortayı, açıortayı ve yüksekliği çözümlenebilir a) Üçgende kenarortayı, açıortayı ve yüksekliği belirler. b) Üçgende kenarortayı, açıortayı ve yükseklik arasındaki ilişkileri belirler.	Üçgende kenarortayı, açıortayı ve yükseklik kavramlarının incelenmesine yönelik geometrik bir öğrenme çıktısıdır. Bu öğrenme çıktısında sayı hissi ve bileşenine rastlanmamıştır.
8.Sınıf	Geometrik Şekiller	MAT.8.3.1. Matematiksel araç ve teknoloji yardımıyla üçgenin kenarları ve açıları arasındaki ilişkiyi yorumlayabilme a) Üçgenin kenar ve açı özelliklerini inceler. b) Üçgenin kenar uzunluklarının büyüklüğüne göre açılarının ölçülerini, açılarının ölçülerinin büyüklüğüne göre kenar uzunluklarını sıralar. c) Üçgenin kenar uzunlukları ve açı ölçüleri arasındaki ilişkiyi ifade eder.	Öğrenim çıktısının süreç bileşenlerinde kenar uzunluklarının ve açı ölçülerinin büyüklüklerine göre sıralanması ifadesi yer almaktadır. Bu nedenle bu öğrenim çıktısı “sayıların büyüklüğü” bileşeni içerisine dâhil edilmiştir.

Geçerlilik ve Güvenirlilik

Nitel araştırmalarda geçerlik ve güvenilirlik, araştırma sürecinin tutarlılığı, şeffaflığı ve inandırıcılığı ile ilişkilidir. Bu çalışmada araştırmanın inandırıcılığını artırmak amacıyla veri toplama ve analiz süreçleri ayrıntılı biçimde açıklanmış ve analiz süreci sistematik bir çerçevede yürütülmüştür. Araştırmada kullanılan analiz çerçevesi, alanyazında yer alan ve ölçülebilir temel bileşenler sunan sayı hissi sınıflandırmasına dayandırılmıştır (Gülbağcı-Dede, 2015). Böylece analiz süreci kuramsal temele oturtularak kavramsal tutarlılık sağlanmıştır.

İç geçerliği güçlendirmek amacıyla kodlama süreci çoklu araştırmacı yaklaşımıyla yürütülmüştür. Öğretim programında yer alan öğrenme çıktıları, araştırmacılar tarafından bağımsız olarak kodlanmış ve elde edilen sonuçlar karşılaştırılmıştır. Kodlamalar arasındaki farklılıklar tartışılarak uzlaşılı yoluyla giderilmiştir. Ayrıca nitel araştırma konusunda deneyimli bir uzmanın görüşüne başvurulmuş ve uzman kodlaması ile araştırmacı kodlamaları karşılaştırılmıştır. Bu süreç, araştırmanın doğrulanabilirliğini artırmaya yönelik bir denetim mekanizması olarak kullanılmıştır.

Kodlayıcılar arasındaki tutarlılığı belirlemek amacıyla Miles ve Huberman (1994) tarafından önerilen güvenilirlik formülü Görüş Birliği / (Görüş Birliği + Görüş Ayrılığı) kullanılmıştır. Yapılan hesaplama sonucunda kodlayıcılar arası uyum oranı %96 olarak bulunmuştur. Bu oran, analiz sürecinde yüksek düzeyde tutarlılık sağlandığını göstermektedir.

Dış geçerlik açısından ise araştırma süreci ayrıntılı biçimde betimlenmiş; veri kaynağı, analiz çerçevesi ve kodlama kriterleri açıkça ortaya konulmuştur. Böylece benzer çalışmalar yürütecek araştırmacılar için süreç izlenebilir ve tekrar edilebilir hâle getirilmiştir.

BULGULAR

Bu bölümde Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında yer alan öğrenme çıktılarının sayı hissi ve sayı hissi bileşenleri açısından incelenmesi sonucunda elde edilen bulgular sunulmaktadır. Analiz sürecinde öncelikle programda yer alan öğrenme çıktılarının sınıf düzeylerine ve temalara göre dağılımları belirlenmiştir. Bu işlem, öğretim programının genel yapısını ortaya koymak ve sayı hissi ile ilişkilendirilebilecek öğrenme çıktılarının hangi sınıf düzeylerinde ve temalarda yoğunlaştığını belirlemek amacıyla gerçekleştirilmiştir. Daha sonra öğrenme çıktıları, sayı hissi ve sayı hissini temel bileşenleri doğrultusunda analiz edilerek sınıf düzeyleri ve temalar bağlamında değerlendirilmiştir. Çalışmanın bulgularını yazmadan öncelikle tüm sınıf düzeylerinde ve temalarda yer alan öğrenme çıktılarının sayıları belirlenmiştir. Elde edilen veriler aşağıda Tablo 2’de gösterilmiştir.

Tablo 2. Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Öğretim Programındaki Sınıf Düzeyi ve Temalara Göre Öğrenme Çıktıları Sayıları

Temalar	5.sınıf	6.sınıf	7.sınıf	8.sınıf	Toplam
Sayılar ve Nicelikler	4	8	7	4	23
İşlemlerle Cebirsel Düşünme	4	3	4	4	15
Geometrik Şekiller	7	4	2	6	19
Geometrik Nicelikler	4	6	10	3	23
İstatistiksel Araştırma Süreci	2	2	2	2	8
Veriden Olasılığa	2	1	3	1	7
Dönüşüm	-	-	2	3	5
Toplam	23	24	30	23	100

Tablo 2 incelendiğinde Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında toplam 100 öğrenme çıktısı bulunduğu görülmektedir. Sınıf düzeylerine göre dağılıma bakıldığında öğrenme çıktılarının 5. sınıfta 23, 6. sınıfta 24, 7. sınıfta 30 ve 8. sınıfta 23 olduğu görülmektedir. Buna göre öğrenme çıktılarının en fazla 7. sınıf düzeyinde, en az ise 5. ve 8. sınıf düzeylerinde yer aldığı söylenebilir.

Temalar açısından incelendiğinde, öğrenme çıktılarının en fazla “Sayılar ve Nicelikler” ile “Geometrik Nicelikler” temalarında yoğunlaştığı görülmektedir. Her iki temada da 23’er öğrenme çıktısı bulunmaktadır. Bu durum, programda sayı kavramı, nicelik ilişkileri ve ölçme ile ilişkili matematiksel becerilere önemli bir yer verildiğini göstermektedir. Bununla birlikte “Geometrik Şekiller” teması 19 öğrenme çıktısı ile programda önemli bir yer tutmaktadır. Öğrenme çıktılarının daha sınırlı sayıda yer aldığı temalar ise “İşlemlerle Cebirsel Düşünme” (15), “İstatistiksel Araştırma Süreci” (8), “Veriden Olasılığa” (7) ve “Dönüşüm” (5) temalarıdır.

Özellikle Dönüşüm temasının yalnızca 7. ve 8. sınıf düzeylerinde yer aldığı ve toplam öğrenme çıktısı sayısının diğer temalara göre oldukça düşük olduğu dikkat çekmektedir.

Genel olarak değerlendirildiğinde, Türkiye Yüzyılı Maarif Modeli ortaokul matematik öğretim programında öğrenme çıktılarının temalar arasında dengeli sayılabilecek bir dağılım gösterdiği, ancak bazı temalarda (özellikle sayılar ve nicelikler ile geometrik nicelikler) daha yoğun bir öğrenme çıktısının bulunduğu görülmektedir. Bu dağılım, programın matematiksel kavramların niceliksel ve geometrik boyutlarına güçlü bir vurgu yaptığını göstermektedir.

Tablo 2’de sunulan öğrenme çıktılarının sınıf düzeyi ve temalara göre dağılımı, öğretim programının yapısal özelliklerini ortaya koymasının yanı sıra sayı hissi bağlamında yapılacak analizler için de önemli bir çerçeve sunmaktadır. Sayı hissi, matematik öğretiminde yalnızca belirli bir öğrenme alanına özgü bir beceri olmayıp sayılar, işlemler, nicelik ilişkileri ve ölçme gibi farklı matematiksel içeriklerde ortaya çıkabilen çok boyutlu bir yapıyı ifade etmektedir. Bu nedenle öğretim programında yer alan tüm temalar kapsamlı bir biçimde incelenmiş ve öğrenme çıktıları sayı hissi bileşenleri ile ilişkileri bakımından değerlendirilmiştir. Öğrenme çıktılarının temalar ve sınıf düzeyleri açısından dağılımının belirlenmesi, sayı hissi ile ilişkili öğrenme çıktıların program içerisindeki konumunu ve yoğunluğunu ortaya koymak açısından araştırmanın önemli bir aşamasını oluşturmaktadır. Bu bağlamda Tablo 2’de sunulan bulgular, öğretim programında sayı hissi ile ilişkilendirilebilecek öğrenme çıktılarının hangi içerik alanlarında yer aldığını belirlemeye yönelik gerçekleştirilen sonraki analizler için temel bir referans noktası oluşturmaktadır.

Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Öğretim Programında Sınıf Düzeylerine Göre Sayı Hissi ve Bileşenlerine Yönelik Bulgular

Ortaokul matematik öğretim programında yer alan öğrenme çıktılarının sayı hissi ile ilişkisini ortaya koyabilmek amacıyla öncelikle her sınıf düzeyinde bulunan toplam öğrenme çıktısı sayısı belirlenmiş ve ardından sayı hissi bileşenleri ile ilişkili olduğu değerlendirilen öğrenme çıktıları tespit edilmiştir. Bu doğrultuda elde edilen veriler sınıf düzeylerine göre sayısal olarak karşılaştırılmış ve yüzdeler dağılımları hesaplanmıştır. Söz konusu dağılım Tablo 3’te sunulmaktadır.

Tablo 3. Sınıf Düzeyine Göre Sayı Hissi ile İlgili Öğrenme Çıktısı Sayısı

Sınıf Düzeyi	Sayı Hissi ile İlgili Öğrenme Çıktısı Sayısı	Toplam öğrenme çıktısı sayısı	Yüzde(%)
5.sınıf	11	23	%47,8
6.sınıf	13	24	%54,2
7.sınıf	14	30	%46,7
8.sınıf	7	23	%30,4
Toplam	45	100	%45

Tablo 3 incelendiğinde ortaokul matematik öğretim programında toplam 100 öğrenme çıktısı bulunduğu ve bunlardan 45'inin sayı hissi ile ilişkili olduğu görülmektedir. Bu durum, öğretim programındaki öğrenme çıktılarının yaklaşık %45'inin sayı hissi bileşenleri ile ilişkilendirilebildiğini göstermektedir.

Sınıf düzeylerine göre incelendiğinde, 5. sınıfta yer alan 23 öğrenme çıktısının 11'inin (%47,8) sayı hissi ile ilişkili olduğu belirlenmiştir. 6. sınıfta ise toplam 24 öğrenme çıktısından 13'ünün (%54,2) sayı hissi ile ilişkili olduğu görülmektedir. Bu sonuç, sayı hissi ile ilişkili öğrenme çıktılarının en yüksek oranda 6. sınıf düzeyinde yer aldığını göstermektedir. 7. sınıf düzeyinde toplam 30 öğrenme çıktısının 14'ünün (%46,7) sayı hissi ile ilişkilendirildiği belirlenmiştir. Buna karşın 8. sınıfta yer alan 23 öğrenme çıktısından yalnızca 7'sinin (%30,4) sayı hissi ile ilişkili olduğu görülmektedir. Bu sonuç, sayı hissi ile ilişkili öğrenme çıktılarının en düşük oranda 8. sınıf düzeyinde yer aldığını göstermektedir.

Genel olarak değerlendirildiğinde, öğretim programında sayı hissi ile ilişkili öğrenme çıktılarının özellikle 5., 6. ve 7. sınıf düzeylerinde daha yoğun biçimde yer aldığı, buna karşın 8. sınıf düzeyinde bu oranın görece azaldığı görülmektedir. Bu durum, üst sınıf düzeylerinde matematik öğretiminin daha çok cebirsel ve formal işlemlere yönelmesi ile ilişkilendirilebilir. Öğretim programında yer alan öğrenme çıktılarının sayı hissi ile ilişkili olup olmadıklarının belirlenmesinin ardından, sayı hissi ile ilişkili olduğu tespit edilen öğrenme çıktıları sayı hissi bileşenlerine göre ayrıntılı olarak incelenmiştir. Bu doğrultuda öğrenme çıktıları, Gülbağcı-Dede (2015) tarafından ortaya konulan sayı hissi temel bileşenleri esas alınarak sayıların anlamı, sayıların büyüklüğü, esnek işlem yapma ve tahmin etme üzere dört kategori altında sınıflandırılmıştır. Elde edilen bulgular sınıf düzeylerine göre karşılaştırmalı olarak analiz edilmiş ve sonuçlar Tablo 4'te sunulmuştur.

Tablo 4. Sınıf Düzeylerine Göre Öğrenme Çıktılarının Sayı Hissi Bileşenlerine Dağılımı

Sınıf Düzeyi	Sayıların Anlamı	Sayıların Büyüklüğü	Esnek İşlem Yapma	Tahmin Etme
5.sınıf	4	4	3	5
6.sınıf	7	1	6	4
7.sınıf	6	3	2	3
8.sınıf	2	3	-	3
Toplam	19	11	11	15

Tablo 4 incelendiğinde, öğretim programında sayı hissi ile ilişkili öğrenme çıktılarının dört temel bileşen arasında farklı düzeylerde dağıldığı görülmektedir. Genel dağılım incelendiğinde sayıların anlamı bileşenine yönelik 19 öğrenme çıktısı, tahmin etme bileşenine yönelik 15 öğrenme çıktısı, sayıların büyüklüğü bileşenine yönelik 11 öğrenme çıktısı ve esnek işlem yapma bileşenine yönelik 11 öğrenme çıktısı bulunduğu belirlenmiştir. Bu bulgu, öğretim programında sayıların anlamını kavramaya yönelik öğrenme çıktılarının diğer bileşenlere kıyasla daha fazla yer aldığını göstermektedir.

Sınıf düzeyleri açısından incelendiğinde, 5. sınıfta sayıların anlamı ve sayıların büyüklüğü bileşenlerine yönelik dörder öğrenme çıktısı bulunurken, esnek işlem yapma bileşenine yönelik üç ve tahmin etme bileşenine yönelik beş öğrenme çıktısı yer almaktadır. Bu durum, özellikle 5. sınıf düzeyinde öğrencilerin sayıların farklı temsillerini anlamlandırmaları ve tahmin becerilerini geliştirmeye yönelik öğrenme çıktılarının öne çıktığını göstermektedir.

6. sınıf düzeyinde sayıların anlamı bileşeni yedi öğrenme çıktısı ile en yüksek değere sahip bileşen olarak dikkat çekmektedir. Bununla birlikte esnek işlem yapma bileşenine yönelik altı ve tahmin etme bileşenine yönelik dört öğrenme çıktısı yer alırken sayıların büyüklüğü bileşeni yalnızca bir öğrenme çıktısı ile temsil edilmektedir. Bu durum 6. sınıf düzeyinde özellikle sayıların yapısal özelliklerinin anlaşılması ve işlemlerin farklı stratejilerle ele alınmasına yönelik öğrenme çıktılarının ağırlık kazandığını göstermektedir.

7. sınıf düzeyinde ise sayıların anlamı bileşenine yönelik altı öğrenme çıktısı bulunurken sayıların büyüklüğü bileşenine yönelik üç, esnek işlem yapma bileşenine yönelik iki ve tahmin etme bileşenine yönelik üç öğrenme çıktısı yer almaktadır. Bu dağılım 7. sınıfta sayıların anlamlandırılmasına yönelik öğrenme çıktılarının hâlen önemli bir yer tuttuğunu göstermektedir.

8. sınıf düzeyinde ise sayıların anlamı bileşenine yönelik iki öğrenme çıktısı bulunurken sayıların büyüklüğü ve tahmin etme bileşenlerine yönelik üçer öğrenme çıktısı yer almakta, esnek işlem yapma bileşenine yönelik herhangi bir öğrenme çıktısına rastlanmamaktadır. Bu durum üst sınıf düzeyine geçildikçe öğretim programında sayı hissini bazı bileşenlerine yönelik öğrenme çıktılarının azaldığını göstermektedir.

Genel olarak değerlendirildiğinde öğretim programında sayı hissi bileşenlerinin tümüne yer verilmekle birlikte, öğrenme çıktılarının özellikle sayıların anlamı ve tahmin etme bileşenlerinde yoğunlaştığı, buna karşın sayıların büyüklüğü ve esnek işlem yapma bileşenlerinin daha sınırlı düzeyde temsil edildiği görülmektedir.

Türkiye Yüzyılı Maarif Modeli Ortaokul Matematik Öğretim Programında Temalara Göre Sayı Hissi ve Bileşenlerine Yönelik Bulgular

Öğretim programında yer alan öğrenme çıktılarının sayı hissi ile ilişkili olup olmadıklarının sınıf düzeylerine göre incelenmesinin ardından, bu öğrenme çıktılarının temalara göre dağılımı da analiz edilmiştir. Bu doğrultuda öğretim programında yer alan her bir temadaki toplam öğrenme çıktısı sayısı belirlenmiş ve sayı hissi ile ilişkilendirilen öğrenme çıktıları tespit edilmiştir. Böylece öğretim programındaki farklı temaların sayı hissi ile ne ölçüde ilişkili olduğu ortaya konulmaya çalışılmıştır. Elde edilen bulgular Tablo 5'te sunulmaktadır.

Tablo 5. Temalara Göre Sayı Hissi ile İlgili Öğrenme Çıktılarının Sayısı

Temalar	Sayı Hissi ile İlgili Öğrenme Çıktısı Sayısı	Toplam öğrenme çıktısı sayısı	Yüzde(%)
Sayılar ve Nicelikler	22	23	%95,6
İşlemlerle Cebirsel Düşünme	6	15	%40
Geometrik Şekiller	2	19	%10,5
Geometrik Nicelikler	10	23	%43,5
İstatistiksel Araştırma Süreci	0	8	0
Veriden Olasılığa	4	7	%57,1
Dönüşüm	1	5	%20
Toplam	45	100	%45

Tablo 5 incelendiğinde sayılar ve nicelikler temasında yer alan 23 öğrenme çıktısından 22'sinin (%95,6) sayı hissi ile ilişkili olduğu görülmektedir. Bu durum sayı hissi ile ilişkili öğrenme çıktılarının en yoğun biçimde bu temada yer aldığını göstermektedir. Bu bulgu, sayı hissini doğrudan sayılarla ve sayıların farklı temsilleriyle ilişkili olması nedeniyle beklenen bir durum olarak değerlendirilebilir. İşlemlerle cebirsel düşünme temasında yer alan 15 öğrenme çıktısının 6'sının (%40) sayı hissi ile ilişkili olduğu belirlenmiştir. Bu durum, söz konusu temada yer alan bazı öğrenme çıktılarının sayılar ve işlemler arasındaki ilişkileri anlamlandırmaya yönelik olmasıyla açıklanabilir. Geometrik nicelikler temasında yer alan 23 öğrenme çıktısından 10'unun (%43,5) sayı hissi ile ilişkili olduğu görülmektedir. Bu durum özellikle ölçme, büyüklük karşılaştırma ve tahmin gibi süreçlerin sayı hissi ile ilişkilendirilebilmesi ile açıklanabilir. Buna karşılık Geometrik şekiller temasında yer alan 19 öğrenme çıktısından yalnızca 2'sinin (%10,5) sayı hissi ile ilişkili olduğu görülmektedir. Benzer şekilde dönüşüm temasında yer alan 5 öğrenme çıktısından 1'i (%20) sayı hissi ile ilişkilendirilmiştir. Bu

temalarda sayı hissi ile ilişkili öğrenme çıktılarının sınırlı düzeyde yer aldığı dikkat çekmektedir.

Öte yandan veriden olasılığa temasında yer alan 7 öğrenme çıktısından 4'ünün (%57,1) sayı hissi ile ilişkili olduğu belirlenmiştir. Özellikle olasılık değerlerinin büyüklük ilişkisi içinde değerlendirilmesi ve tahmin yapılması gibi süreçlerin sayı hissi ile ilişkilendirilebildiği görülmektedir. Bununla birlikte İstatistiksel araştırma süreci temasında yer alan 8 öğrenme çıktısının hiçbirinin sayı hissi ile ilişkilendirilmediği belirlenmiştir. Bu durum söz konusu temanın daha çok veri toplama, veri düzenleme ve yorumlama süreçlerine odaklanmasıyla açıklanabilir. Genel olarak değerlendirildiğinde öğretim programında sayı hissi ile ilişkili öğrenme çıktılarının özellikle sayılar ve nicelikler teması başta olmak üzere sayılarla doğrudan ilişkili temalarda yoğunlaştığı, buna karşın geometri ve veri odaklı temalarda daha sınırlı düzeyde yer aldığı görülmektedir.

Öğretim programında sayı hissi ile ilişkili öğrenme çıktılarının temalara göre dağılımı belirlendikten sonra, bu öğrenme çıktılarının sayı hissi bileşenleri açısından temalar bazında nasıl dağıldığı da incelenmiştir. Bu doğrultuda sayı hissi ile ilişkili olduğu belirlenen öğrenme çıktıları; sayıların anlamı, sayıların büyüklüğü, esnek işlem yapma ve tahmin etme bileşenleri çerçevesinde sınıflandırılmış ve her temada yer alan öğrenme çıktılarının hangi sayı hissi bileşenleri ile ilişkilendirildiği belirlenmiştir. Elde edilen bulgular Tablo 6'da sunulmaktadır.

Tablo 6. Temalara Göre Öğrenme Çıktılarının Sayı Hissi Bileşenlerine Dağılımı

Temalar	Sayıların Anlamı	Sayıların Büyüklüğü	Esnek İşlem Yapma	Tahmin Etme
Sayılar ve Nicelikler	14	5	6	4
İşlemlerle Cebirsel Düşünme	3	-	2	-
Geometrik Şekiller	-	1	-	1
Geometrik Nicelikler	2	3	3	5
İstatistiksel Araştırma Süreci	-	-	-	-
Veriden Olasılığa	-	2	-	4
Dönüşüm	-	-	-	1
Toplam	19	11	11	15

Tablo 6 incelendiğinde öğretim programında sayı hissi ile ilişkili öğrenme çıktılarının farklı temalarda ve farklı sayı hissi bileşenlerinde yoğunlaştığı görülmektedir. Genel dağılıma bakıldığında sayıların anlamı bileşeni 19 öğrenme çıktısı ile en fazla temsil edilen bileşen olurken, tahmin etme bileşeni 15 öğrenme çıktısı, sayıların büyüklüğü ve esnek işlem yapma bileşenleri ise 11'er öğrenme çıktısı ile temsil edilmektedir.

Temalar açısından incelendiğinde sayılar ve nicelikler temasının sayı hissi bileşenleri açısından en zengin tema olduğu görülmektedir. Bu temada sayıların anlamı bileşenine yönelik 14, sayıların büyüklüğü bileşenine yönelik 5, esnek işlem yapma bileşenine yönelik 6 ve tahmin

etme bileşenine yönelik 4 öğrenme çıktısı yer almaktadır. Bu durum söz konusu temanın doğrudan sayı kavramı, sayıların temsilleri ve sayılar arası ilişkiler ile ilgili olmasıyla açıklanabilir. İşlemlerle cebirsel düşünme temasında ise sayıların anlamı bileşenine yönelik 3 ve esnek işlem yapma bileşenine yönelik 2 öğrenme çıktısı bulunurken sayıların büyüklüğü ve tahmin etme bileşenlerine yönelik herhangi bir öğrenme çıktısına rastlanmamaktadır. Bu durum söz konusu temada daha çok cebirsel ilişkilerin ve işlemsel yapıların ele alınmasından kaynaklanabilir. Geometrik şekiller temasında sayı hissi ile ilişkili öğrenme çıktılarının oldukça sınırlı olduğu görülmektedir. Bu temada sayıların büyüklüğü ve tahmin etme bileşenlerine yönelik birer öğrenme çıktısı bulunmaktadır. Geometrik nicelikler temasında ise sayı hissini farklı bileşenlerinin daha dengeli biçimde temsil edildiği görülmektedir. Bu temada sayıların anlamı bileşenine yönelik 2, sayıların büyüklüğü bileşenine yönelik 3, esnek işlem yapma bileşenine yönelik 3 ve tahmin etme bileşenine yönelik 5 öğrenme çıktısı yer almaktadır. Özellikle ölçme, büyüklük karşılaştırma ve tahmin süreçlerinin bu temada ön plana çıktığı görülmektedir. Veriden olasılığa temasında sayıların büyüklüğü bileşenine yönelik 2 ve tahmin etme bileşenine yönelik 4 öğrenme çıktısı bulunurken, diğer bileşenlere yönelik herhangi bir öğrenme çıktısına rastlanmamaktadır. Bu durum olasılık konularının doğası gereği tahmin ve büyüklük ilişkileri ile bağlantılı olmasıyla açıklanabilir. Öte yandan istatistiksel araştırma süreci temasında sayı hissi bileşenleri ile ilişkilendirilen herhangi bir öğrenme çıktısına rastlanmamıştır. Dönüşüm temasında ise yalnızca tahmin etme bileşeni ile ilişkili bir öğrenme çıktısı bulunmaktadır.

Genel olarak değerlendirildiğinde öğretim programında sayı hissi bileşenlerinin özellikle Sayılar ve Nicelikler ve Geometrik Nicelikler temalarında daha yoğun biçimde yer aldığı; buna karşın geometri ve veri temalarında daha sınırlı düzeyde temsil edildiği görülmektedir.

SONUÇ VE TARTIŞMA

Bu araştırmada Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında yer alan öğrenme çıktıları sayı hissi ve sayı hissini temel bileşenleri açısından incelenmiştir. Araştırma sonucunda öğretim programında yer alan toplam 100 öğrenme çıktısından 45'inin (%45) sayı hissi ile ilişkili olduğu belirlenmiştir. Bu bulgu, öğretim programındaki öğrenme çıktılarının önemli bir bölümünün sayı hissi bileşenleri ile ilişkilendirilebildiğini göstermektedir. Sayı hissi, sayıları anlamlandırma, sayılar arasındaki büyüklük ilişkilerini kavrama, işlemleri esnek biçimde gerçekleştirme ve sonuçların akla yatkınlığını değerlendirme gibi becerileri içeren temel bir matematiksel yeterlik olarak tanımlanmaktadır (Gülbağcı-Dede, 2015). Bu açıdan değerlendirildiğinde öğretim programında sayı hissi ile ilişkili öğrenme

çıktılarının belirli bir düzeyde yer alması matematiksel düşünme becerilerinin geliştirilmesi açısından önemli bir durum olarak değerlendirilebilir.

Araştırma bulgularında sayı hissi ile ilişkili öğrenme çıktılarının sınıf düzeylerine göre dağılımı incelendiğinde en yüksek oranın 6. sınıf düzeyinde (%54,2) olduğu, en düşük oranın ise 8. sınıf düzeyinde (%30,4) olduğu görülmektedir. Bu durum sayı hissi ile ilişkili öğrenme çıktılarının özellikle ortaokulun ilk yıllarında daha yoğun biçimde yer aldığını göstermektedir. Benzer şekilde 2018 ortaokul matematik öğretim programının sayı hissi bileşenleri açısından incelendiği bir çalışmada da sayı hissi ile ilişkili kazanımların özellikle alt sınıf düzeylerinde daha yoğun olduğu ve sınıf düzeyi arttıkça bu kazanımların azalma eğilimi gösterdiği belirlenmiştir (Acar & Peker, 2021; Karabey vd., 2019). Bu açıdan bakıldığında mevcut çalışmanın bulguları söz konusu araştırmanın sonuçları ile paralellik göstermektedir. Bu durum, matematik öğretiminde üst sınıf düzeylerine doğru ilerledikçe öğretimin daha çok cebirsel işlemler ve formal matematiksel süreçler üzerine yoğunlaşmasıyla açıklanabilir.

Araştırmada sayı hissi ile ilişkili öğrenme çıktıları sayı hissini temel bileşenleri açısından incelendiğinde en fazla temsil edilen bileşenin sayıların anlamı olduğu belirlenmiştir. Programda toplam 19 öğrenme çıktısının bu bileşen kapsamında değerlendirildiği görülmektedir. Sayıların anlamı bileşenini sırasıyla tahmin etme (15), sayıların büyüklüğü (11) ve esnek işlem yapma (11) bileşenleri izlemektedir. Bu sonuç, öğretim programında özellikle sayıların farklı temsillerinin anlaşılması ve sayıların yapısal özelliklerinin kavranmasına yönelik öğrenme çıktılarının ön plana çıktığını göstermektedir. Sayıların anlamı bileşeninin sayı hissini en temel boyutlarından biri olduğu ve öğrencilerin sayıları anlamlı matematiksel nesnelere kavramalarını sağladığı ifade edilmektedir (Gülbağcı-Dede, 2015). Bu açıdan değerlendirildiğinde öğretim programında sayıların anlamına yönelik öğrenme çıktılarının yüksek düzeyde temsil edilmesi olumlu bir durum olarak değerlendirilebilir. Bu bulgu alanyazında yapılan bazı öğretim programı inceleme çalışmalarıyla da benzerlik göstermektedir. Örneğin ilköğretim matematik öğretim programının sayı hissi bileşenleri açısından incelendiği bir çalışmada programda yer alan kazanımların büyük bir kısmının sayıların anlamı ve tahmin etme bileşenleri ile ilişkili olduğu belirlenmiştir (Çetin & Öztürk, 2020). Dolayısıyla mevcut çalışmada elde edilen sonuçların söz konusu araştırmanın bulguları ile paralellik gösterdiği söylenebilir. Bununla birlikte bazı çalışmalarda esnek işlem yapma bileşeninin programlarda daha sınırlı düzeyde yer aldığı da vurgulanmaktadır (Karabey vd., 2019). Mevcut çalışmada da esnek işlem yapma bileşeninin toplam öğrenme çıktıları içinde görece sınırlı bir oranda temsil edilmesi bu bulgularla örtüşmektedir.

Araştırmada öğrenme çıktılarının temalara göre dağılımı incelendiğinde sayı hissi ile ilişkili öğrenme çıktılarının büyük ölçüde sayılar ve nicelikler temasında yoğunlaştığı belirlenmiştir. Bu temada yer alan 23 öğrenme çıktısından 22'sinin (%95,6) sayı hissi ile ilişkili olması dikkat çekici bir bulgudur. Bu durum sayı hissini doğrudan sayılar, sayılar arası ilişkiler ve sayısal temsiller ile ilişkili olması nedeniyle beklenen bir sonuç olarak değerlendirilebilir. Benzer şekilde öğretim programlarının sayı hissi açısından incelendiği bazı araştırmalarda da sayı hissi ile ilişkili kazanımların çoğunlukla sayılar ve işlemler öğrenme alanında yoğunlaştığı belirtilmektedir (Çekirdekci & Yorulmaz, 2021; Karabey vd., 2019). Bu açıdan mevcut çalışmanın bulguları alanyazındaki bu sonuçlarla paralellik göstermektedir.

Bununla birlikte araştırma bulgularında geometri temaları ve veri temalarında sayı hissi ile ilişkili öğrenme çıktılarının oldukça sınırlı olduğu görülmektedir. Özellikle istatistiksel araştırma süreci temasında sayı hissi ile ilişkilendirilen herhangi bir öğrenme çıktısına rastlanmamıştır. Bu durum söz konusu temanın daha çok veri toplama, veri düzenleme ve yorumlama süreçlerine odaklanmasıyla açıklanabilir. Benzer şekilde geometrik şekiller ve dönüşüm temalarında da sayı hissi ile ilişkili öğrenme çıktılarının oldukça sınırlı olduğu görülmektedir. Bu bulgu alanyazında yer alan bazı çalışmalarla da örtüşmektedir. Nitekim öğretim programlarının sayı hissi açısından incelendiği araştırmalarda sayı hissini çoğunlukla sayısal içeriklerde yoğunlaştığı, geometri ve veri temalarında ise daha sınırlı düzeyde temsil edildiği belirtilmektedir (Acar & Peker, 2021; Çetin & Öztürk, 2020).

Araştırmada dikkat çeken bir diğer bulgu ise veriden olasılığa temasında sayı hissi ile ilişkili öğrenme çıktılarının görece yüksek bir oranda yer almasıdır (%57,1). Özellikle olasılık değerlerinin büyüklük ilişkileri içerisinde değerlendirilmesi ve olayların gerçekleşme olasılığına yönelik tahminlerde bulunulması gibi süreçlerin sayı hissi ile ilişkilendirilebildiği görülmektedir. Olasılık konularında tahmin ve büyüklük karşılaştırma süreçlerinin önemli bir yer tuttuğu alanyazın da vurgulanmaktadır. Bu açıdan bakıldığında söz konusu bulgunun matematik öğretiminin doğası ile uyumlu olduğu söylenebilir.

Genel olarak değerlendirildiğinde araştırma bulguları Türkiye Yüzyılı Maarif Modeli ortaokul matematik öğretim programının sayı hissi bileşenlerini belirli bir düzeyde içerdiğini göstermektedir. Bununla birlikte sayı hissi bileşenlerinin program içerisinde eşit bir dağılım göstermediği ve özellikle sayıların anlamı ve tahmin etme bileşenlerinin daha yoğun biçimde temsil edildiği görülmektedir. Ayrıca sayı hissi ile ilişkili öğrenme çıktılarının büyük ölçüde sayılar ve nicelikler teması içerisinde yoğunlaşması programın bazı matematiksel içerik alanlarında sayı hissi ile daha güçlü ilişkilendirilebileceğini göstermektedir. Sonuç olarak

Türkiye Yüzyılı Maarif Modeli ortaokul matematik öğretim programının sayı hissi gelişimini destekleyebilecek önemli öğrenme çıktıları içerdiği söylenebilir.

ÖNERİLER

Bu araştırmada Türkiye Yüzyılı Maarif Modeli ortaokul matematik dersi öğretim programında yer alan öğrenme çıktıları sayı hissi bileşenleri açısından incelenmiş ve elde edilen bulgular doğrultusunda aşağıdaki öneriler geliştirilmiştir.

Öncelikle araştırma bulguları öğretim programındaki öğrenme çıktılarının yaklaşık %45'inin sayı hissi ile ilişkili olduğunu göstermektedir. Bu durum öğretim programının sayı hissi gelişimini destekleyen önemli bir potansiyele sahip olduğunu ortaya koymaktadır. Ancak sayı hissi bileşenlerinin öğretim programı içerisinde eşit biçimde temsil edilmediği görülmektedir. Özellikle sayıların anlamı ve tahmin etme bileşenlerinin daha yoğun biçimde yer aldığı, buna karşın sayıların büyüklüğü ve esnek işlem yapma bileşenlerinin görece daha sınırlı düzeyde temsil edildiği belirlenmiştir. Bu doğrultuda öğretim programının geliştirilmesi sürecinde sayı hissinin tüm bileşenlerinin daha dengeli bir biçimde yer almasına yönelik düzenlemeler yapılması önerilebilir.

Araştırma bulgularına göre sayı hissi ile ilişkili öğrenme çıktıları özellikle sayılar ve nicelikler temasında yoğunlaşmaktadır. Buna karşın geometrik şekiller, dönüşüm ve istatistiksel araştırma süreci temalarında sayı hissi ile ilişkili öğrenme çıktılarının oldukça sınırlı olduğu görülmektedir. Bu doğrultuda öğretim programı geliştirilirken geometri, veri analizi ve istatistik gibi temalarda da sayı hissi ile ilişkilendirilebilecek öğrenme çıktılarının artırılması önerilebilir. Özellikle ölçme, büyüklük karşılaştırma, tahmin ve akıl yürütme süreçlerinin bu temalarla ilişkilendirilmesi öğrencilerin matematiksel düşünme becerilerinin daha bütüncül biçimde gelişmesine katkı sağlayabilir.

Araştırma sonuçları ayrıca sayı hissi ile ilişkili öğrenme çıktılarının özellikle 5., 6. ve 7. sınıf düzeylerinde daha yoğun, 8. sınıf düzeyinde ise daha sınırlı düzeyde yer aldığını göstermektedir. Bu doğrultuda üst sınıf düzeylerinde de sayı hissi ile ilişkili öğrenme çıktılarının artırılması önerilebilir. Özellikle cebirsel düşünme ve problem çözme süreçlerinde sayı hissi becerilerinin kullanılmasına yönelik öğrenme çıktılarının programa dâhil edilmesi öğrencilerin sayılarla daha esnek ve anlamlı ilişkiler kurmalarına katkı sağlayabilir.

Öğretim süreci açısından değerlendirildiğinde öğretmenlerin sayı hissini geliştirmeye yönelik öğretim stratejilerini daha etkin biçimde kullanmaları önerilebilir. Özellikle tahmin etme, zihinden işlem yapma, farklı çözüm yolları geliştirme ve sonuçların akla yatkınlığını

değerlendirme gibi etkinliklerin öğretim süreçlerinde daha fazla yer alması öğrencilerin sayı hissi gelişimini destekleyebilir.

Son olarak bu araştırma yalnızca öğretim programındaki öğrenme çıktılarının incelenmesi ile sınırlıdır. Bu doğrultuda gelecekte yapılacak araştırmalarda sayı hissi ile ilişkili öğrenme çıktılarının ders kitapları, öğretim materyalleri ve sınıf içi uygulamalar bağlamında nasıl ele alındığının incelenmesi önerilebilir. Ayrıca öğretmenlerin sayı hissine yönelik öğretim yaklaşımlarının ve öğrencilerin sayı hissi düzeylerinin incelendiği araştırmaların yapılması, öğretim programının uygulamadaki etkilerinin daha kapsamlı biçimde ortaya konmasına katkı sağlayabilir.

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EPİLEPSİLİ BİREYLERDE ALEKSİTEMİ

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ÖZET

Aleksitimi, bireyin duygularını tanıma, ayırt etme ve sözel olarak ifade etme güçlüğü ile karakterize edilen; dışa dönük düşünme eğilimi ve sınırlı imgesel yaşamla ilişkili çok boyutlu bir kişilik özelliği olarak tanımlanmaktadır. Son yıllarda, kronik nörolojik hastalıklar bağlamında aleksitiminin yaygınlığı ve klinik sonuçları giderek daha fazla araştırılmakta; özellikle epilepsi hastalarında aleksitimik özelliklerin genel popülasyona kıyasla daha yüksek oranlarda görüldüğü bildirilmektedir. Epilepsi, yalnızca nöbetlerle sınırlı bir nörolojik bozukluk olmayıp, bilişsel, duygusal ve psikososyal alanlarda önemli etkiler doğuran bir durumdur. Bu bağlamda aleksitimi, epilepsinin psikiyatrik komorbiditeleri ve yaşam kalitesi üzerindeki etkilerini anlamada kritik bir değişken olarak öne çıkmaktadır. Son yıllarda yapılan çalışmalar, epilepsili bireylerde aleksitimi prevalansının genel popülasyona oranla anlamlı derecede yüksek olduğunu göstermektedir. Bu durumun; özellikle limbik sistemdeki disfonksiyonlar, nöbet odağının lokalizasyonu (özellikle sağ hemisfer ve temporal lob tutulumu) ve nöbet sıklığı ile ilişkili olabileceği düşünülmektedir. Epilepsili bireylerde aleksitimi; depresyon ve anksiyete gibi psikiyatrik komorbiditelerle anlamlı düzeyde ilişkili bulunmuş, bazı çalışmalarda aleksitiminin bu belirtiler üzerinde yordayıcı rol oynayabileceği gösterilmiştir. Bunun yanı sıra, yüksek aleksitimi düzeylerinin düşük yaşam kalitesi, zayıf tedavi uyumu, artmış algılanan stigma ve sınırlı sosyal destek ile ilişkili olduğu bildirilmektedir. Çocuk ve ergen epilepsi hastalarında yapılan çalışmalar da benzer şekilde, aleksitiminin sosyal işlevsellik ve benlik algısı üzerinde olumsuz etkileri olabileceğini ortaya koymaktadır. Sonuç olarak, mevcut literatür epilepsili bireylerde aleksitiminin hem nörobiyolojik hem de psikososyal boyutları olan çok yönlü bir olgu olduğunu göstermektedir. Klinik uygulamada aleksitiminin değerlendirilmesi; psikiyatrik komorbiditelerin erken tanınması, psikoeğitim ve psikoterapötik müdahalelerin planlanması açısından önem taşımaktadır. Bu derlemede, epilepsili bireylerde aleksitimi konusu ele alınmış olup, çeşitli yönleriyle değerlendirilmiştir.

Anahtar Kelimeler: Aleksitimi, Depresyon, Epilepsi, Nöbet

ALEXITHYMIA IN INDIVIDUALS WITH EPILEPSY

ABSTRACT

Alexithymia is defined as a multidimensional personality construct characterized by difficulties in identifying, differentiating, and verbally expressing emotions, along with an externally oriented thinking style and a limited imaginative capacity. In recent years, the prevalence and clinical implications of alexithymia in the context of chronic neurological disorders have increasingly attracted attention. In particular, alexithymic traits have been reported to occur at higher rates in individuals with epilepsy compared to the general population. Epilepsy is not merely a neurological disorder limited to seizures; it is a condition that exerts significant effects on cognitive, emotional, and psychosocial functioning. In this context, alexithymia emerges as a critical variable in understanding the psychiatric comorbidities and quality of life outcomes associated with epilepsy. Recent studies indicate that the prevalence of alexithymia in individuals with epilepsy is significantly higher than in the general population. This association is thought to be related to limbic system dysfunction, localization of the seizure focus (particularly right hemisphere and temporal lobe involvement), and seizure frequency. Alexithymia in individuals with epilepsy has been found to be significantly associated with psychiatric comorbidities such as depression and anxiety, and some studies suggest that alexithymia may have a predictive role in the severity of these symptoms. Furthermore, higher levels of alexithymia have been associated with lower quality of life, poor treatment adherence, increased perceived stigma, and limited social support. Studies conducted in pediatric and adolescent populations with epilepsy similarly demonstrate that alexithymia may negatively affect social functioning and self-perception. In conclusion, the existing literature suggests that alexithymia in individuals with epilepsy is a multifaceted phenomenon encompassing both neurobiological and psychosocial dimensions. The assessment of alexithymia in clinical practice is important for the early identification of psychiatric comorbidities and for planning psychoeducational and psychotherapeutic interventions. In this review, the issue of alexithymia in individuals with epilepsy has been addressed and evaluated from various perspectives.

Keywords: Alexithymia, Depression, Epilepsy, Seizure

1. GİRİŞ

Epilepsi, dünyada her yaştan yaklaşık 50 milyon insanı etkileyen ciddi bir nörolojik bozukluktur (WHO, 2024). Siner sistemi hastalıkları içerisinde en sık görülen 4. hastalık olup ve tekrarlayan nöbetlerle karakterize davranışsal veya motor bozukluklardır (Milligan, 2021; Fiest ve ark., 2017). Epilepsinin temel mekanizması, nöronların aşırı uyarılması ve aşırı

senkronize nöronlar arasında tekrarlayan sinaptik bağlantıların oluşmasıdır (Raflı ve ark., 2023). Dünya çapında her yıl yaklaşık 5 milyon yeni epilepsi vakası teşhis edilmektedir. Yüksek gelirli ülkelerde, her yıl 100.000 kişiden 49'una epilepsi teşhisi konulduğu; düşük ve orta gelirli ülkelerde ise bu rakamın 100.000 kişide 139'a kadar çıktığı tahmin edilmektedir (WHO, 2024). Ülkemizde ise aktif epilepsi tanısı alan 750 bin kişi olduğu belirtilmektedir (Balal ve ark., 2017).

Epilepsili hastalar, nöbet geçirmenin getirdiği duygusal ve fiziksel zorluklarla tutarlı bir şekilde baş edemezlerse duygusal zorluklar ve sıkıntı yaşayabilirler (Cummings, 2004). Aleksitimi birçok psikosomatik hastalığın altında yatan faktör olarak öne sürülmesine rağmen, yapılan araştırmalar epileptik hastaların beyinlerinde aleksitimik hastalarda bulunanlara benzer fonksiyonel bozukluklar ve lezyonlar tespit etmiştir. Ayrıca epilepsili bireylerin, aleksitimik bireylere benzer şekilde, düşüncelerini ve duygularını ifade etmekte zorluk çektiği gösterilmiştir (Keskin ve ark., 2011; Marchi ve ark., 2019). Epileptik hastalarla yapılan çalışmalar, hastaların yüksek aleksitimik özelliklere sahip olduğu ve aleksitimik özelliklerin psikopatolojik değişkenler üzerinde maksimum etkiye sahip olduğu bildirilmiştir (Choi ve ark., 2021; Tombini ve ark., 2020). Yunanca kökenli bir kelime olan aleksitimi, "duygular için söz yokluğu" şeklinde dilimize çevrilmiştir. Başlangıçta psikosomatik hastalarda görülen belirtileri açıklamak amacıyla ortaya atılmışsa da, günümüzde yalnızca bu hastalarda değil, diğer ruhsal ve fiziksel hastalıklarda da sıklıkla görüldüğü vurgulanmaktadır (Sayar ve ark., 2004; Madenci ve ark., 2007; Taymur ve ark., 2007). Aleksitimi, psikojenik non-epileptik nöbet geçiren hastaların %30-91'inde (Sequeira & Silva, 2019), depresyonu olan hastaların %32-51'inde (Saarijärvi ve ark., 2001) ve anksiyete bozukluğu olan hastaların %13-58'inde (Parker ve ark., 1993) bildirilmiştir. Diğer bir çalışmada da benzer şekilde epilepsi hastaları arasında, depresif semptomları olanların %52,6'sında ve anksiyetesi olanların %33,3'ünde aleksitimi mevcuttu. Bu tür psikiyatrik bozukluklar sıklıkla epilepsi ile birlikte görülür. Bu nedenle, aleksitiminin epilepsi bağlamında kapsamlı bir şekilde araştırılmamış olmasına rağmen, epilepsi hastalarında daha yaygın olması beklenmektedir (Choi ve ark., 2021).

Aleksitimiklerin en belirgin özellikleri duygularını fark edip bunları ifade etmede güçlük çekmeleridir. Duygusal işlevlerinde ve kişilerarası ilişkilerinde güçlük çekerler. Aleksitimi duygusal, davranışsal, fizyolojik ve öznel/deneyimsel düzeylerde tüm duyguları ifade etmede zorluk ile karakterizedir (Panayiotou & Constantinou, 2017). Epilepsi hastalarının sağlıklı popülasyona kıyasla duygularını tanıma ve ifade etmede daha fazla zorluk yaşadıkları bildirilmiştir (Tombini ve ark., 2020; Choi ve ark., 2021). Literatürde, sürekli nöbetler, ilaç

kullanımı, diyet uyumsuzluğu ve yaşam tarzı değişiklikleri gibi durumların epilepsi hastalarında aleksitimi artırdığı ve stres varlığında aleksitiminin daha da arttığı bildirilmiştir (Chung & Allen, 2013; Wolf ve ark., 2015; Tombini ve ark., 2020; Choi ve ark., 2021; Keskin ve ark., 2023; Safiye ve ark., 2024). Bireylerin duygularını bastırması veya yaşadıklarını ifade edememesi kaygı ve stresi artırarak bağışıklık sistemini olumsuz etkiler, tedaviye uyumu ve yaşam kalitesini bozar (Aaron ve ark., 2019; Tombini ve ark., 2020).

Birçok çalışmada epilepsi hastalarında aleksitiminin yüksek olduğu gözlemlenmiş olsa da, aleksitimi ile epilepsi hastalığının belirli klinik özellikleri arasındaki ilişki genellikle net değildir. Epilepsi hastalarının tanı alma süresi, hastalığın başlangıcından itibaren geçen zaman dilimiyle ilgilidir. Uzun süre tanı almayan ya da tedaviye geç başlayan hastalarda psikolojik etkilerin daha belirgin olabileceği düşünülse de (Ziegler ve ark., 2012; Jones ve ark., 2013), tanı alma süresi ile aleksitimi arasında güçlü bir ilişki bulmak zordur. Bununla birlikte, erken tanı almış ve tedaviye başlamış hastalarda bile aleksitimi seviyeleri değişken olabilir. Bu durum, hastaların bireysel farklılıkları ve psikolojik yanıtlarının önemli bir rol oynadığını gösterir. Yapılan bazı çalışmalar epilepsi hastalarında erken tanının daha iyi bir psikolojik iyileşme ile ilişkili olduğunu, ancak tanı süresinin aleksitimi üzerinde doğrudan bir etkisi olmadığını ifade etmişlerdir (Hermann ve ark., 2008; Schneider ve ark., 2013; Papageorgiou ve ark., 2015; Jones ve ark., 2017).

Atak sıklığının aleksitimi ile olan ilişkisi konusunda yapılan araştırmalar tutarsız sonuçlar vermektedir. Bazı çalışmalar, daha sık nöbet geçiren hastalarda duygusal farkındalık ve ifade etme zorluklarının daha belirgin olduğunu öne sürerken, diğerleri bu ilişkiyi bulamamıştır (Jones ve ark., 2013; Cacioppo ve ark., 2014; Papageorgiou ve ark., 2015). Bir çalışmada, bir önceki yıl içinde nöbetlerin tekrarlamasının duyguları tanımlamada güçlük ile ilişkili olmasına rağmen, nöbet tekrarının genel aleksitimi üzerinde doğrudan etkileri saptanamamıştır (Choi ve ark., 2021). Depresyonun aleksitimi için önemli bir risk faktörü olduğu (Saarijärvi ve ark., 2001) ve son bir yıl içinde nöbet tekrarı yaşayan hastalarda depresif belirtilerin görülme olasılığının yaklaşık altı kat daha fazla olduğu göz önünde bulundurulduğunda, nöbetleri kontrolsüz olan hastaların aleksitimi yaşama olasılığı daha yüksek olabileceği düşünülmektedir (Choi ve ark., 2021). Epilepsi hastalarında nöbetlerin sıklığı, beyin fonksiyonları üzerinde daha fazla etkide bulunabilir, ancak aleksitimi sadece nöbet sıklığı ile açıklanamaz. Bu durum, epilepsinin türü, nöbetlerin yerleşimi ve hastaların bireysel psikolojik tepkilerinin önemli rol oynadığına işaret eder. Epilepsi tedavisinde kullanılan ilaçlar, nöbetlerin kontrol altına alınmasını sağlasa da bazı ilaçların psikiyatrik yan etkileri olabilir. Antikonvülsan ilaçların

bazen duygu durumunu etkileyebileceği ve psikolojik işlevlerde değişikliklere yol açabileceği bilinmektedir. Ancak ilaç sayısının aleksitimi üzerinde belirgin bir etkisi olduğuna dair literatürde sınırlı çalışmaya rastlanılmıştır (Berkovich ve ark. 2011; Lehman ve ark., 2015). Yapılan bir çalışmada antiepileptik ilaçların çoklu kullanımı doğrudan aleksitimi ile ilişkili bulunurken, kontrol altına alınamayan nöbetler depresif semptomlar aracılığıyla dolaylı yollarla aleksitimi ile ilişkili bulunmuştur (Choi ve ark., 2021).

2. SONUÇ ve ÖNERİLER

Epilepsi hastalarının aleksitimi düzeylerinin çeşitli durumlara bağlı olarak arttığı ve bu durumun bireylerin yaşam kalitesini etkilediği görülmektedir. Ayrıca psikiyatrik bozuklukların epilepsiye eşlik ederek aleksitimiye etkilediği de görülmektedir. Bu nedenle epilepsi hastalığıyla birlikte, eşlik eden psikiyatrik bozuklukları değerlendirirken aleksitimiye de göz önünde bulundurmanın tanı ve tedavi açısından faydalı olacağı düşünülmektedir. Epilepsi gibi yaşamı etkileyen hastalıklara sahip bireylere bakım sağlayan sağlık profesyonellerinin, bireyleri periyodik olarak biyolojik, psikolojik, sosyal ve manevi varlıklar olarak kapsamlı ve bütünsel bir şekilde değerlendirmeleri, sonuçlara göre planlama ve uygulama yapmalarını önerilmektedir.

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EPİLEPSİDE DİYET TEDAVİSİNDE GÜNCEL YAKLAŞIMLAR: KETOJENİK DİYE

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ÖZET

Epilepsi, dünya genelinde yaklaşık 50 milyon insanı etkileyen, tekrarlayan nöbetlerle karakterize kronik bir nörolojik hastalıktır. Farmakolojik tedaviler nöbet kontrolünde temel yaklaşım olmakla birlikte, hastaların yaklaşık üçte birinde ilaca dirençli epilepsi gelişmektedir. Bu durum, tamamlayıcı ve alternatif tedavi stratejilerine olan ilgiyi artırmıştır. Diyet tedavileri, özellikle ketojenik diyet, ilaca dirençli epilepside kanıta dayalı ve etkili bir non-farmakolojik yaklaşım olarak öne çıkmaktadır. Ketojenik diyet; yüksek yağ, yeterli protein ve düşük karbonhidrat içeriği ile ketozis durumunu hedefleyen metabolik bir tedavi modelidir. Klasik ketojenik diyetin yanı sıra modifiye Atkins diyeti, düşük glisemik indeks tedavisi ve orta zincirli trigliserid diyeti gibi alternatif protokoller geliştirilmiştir. Literatürde özellikle pediatrik yaş grubunda nöbet sıklığında %50 ve üzerinde azalma sağlayan yüksek yanıt oranları bildirilmekte; erişkin hastalarda da giderek artan kanıtlar mevcuttur. Güncel yaklaşımlar, bireyselleştirilmiş diyet planlaması, multidisipliner izlem, yan etki yönetimi ve uzun dönem metabolik sonuçların değerlendirilmesini ön plana çıkarmaktadır. Diyetin uygulanmasında gastrointestinal yakınmalar, dislipidemi, büyüme geriliği ve mikronutrient eksiklikleri gibi olası yan etkiler göz önünde bulundurulmalı; düzenli klinik ve biyokimyasal takip sağlanmalıdır. Sonuç olarak, ketojenik diyet, özellikle ilaca dirençli epilepside etkili ve güvenilir bir adjuvan tedavi seçeneği olarak kabul edilmektedir. Bununla birlikte, erişkin popülasyonda uzun dönem etkinlik ve güvenlilik verilerinin artırılmasına yönelik daha geniş örneklemli, randomize kontrollü çalışmalara ihtiyaç bulunmaktadır. Bu derlemede, epilepside ketojenik diyetin güncel uygulama protokolleri, etki mekanizmaları, klinik etkinliği ve güvenlilik profili literatür eşliğinde ele alınmıştır.

Anahtar Kelimeler: Diyet tedavisi, Epilepsi, Ketojenik diyet,

CURRENT APPROACHES TO DIETARY THERAPY IN EPILEPSY: THE KETOGENIC DIET

ABSTRACT

Epilepsy is a chronic neurological disorder characterized by recurrent seizures and affects approximately 50 million people worldwide. Although pharmacological therapies constitute the

main approach to seizure control, nearly one-third of patients develop drug-resistant epilepsy. This situation has increased interest in complementary and alternative treatment strategies. Dietary therapies, particularly the ketogenic diet, have emerged as evidence-based and effective non-pharmacological approaches in drug-resistant epilepsy. The ketogenic diet is a metabolic treatment model that aims to induce ketosis through a high-fat, adequate-protein, and low-carbohydrate composition. In addition to the classical ketogenic diet, alternative protocols such as the modified Atkins diet, low glycemic index treatment, and the medium-chain triglyceride diet have been developed. The literature reports high response rates—especially in the pediatric population—with seizure frequency reductions of 50% or more, and growing evidence also supports its use in adults. Current approaches emphasize individualized dietary planning, multidisciplinary follow-up, management of adverse effects, and evaluation of long-term metabolic outcomes. During implementation, potential adverse effects such as gastrointestinal complaints, dyslipidemia, growth retardation, and micronutrient deficiencies should be considered, and regular clinical and biochemical monitoring should be ensured. In conclusion, the ketogenic diet is regarded as an effective and safe adjuvant treatment option, particularly in drug-resistant epilepsy. However, larger-scale randomized controlled trials are needed to strengthen long-term efficacy and safety data in the adult population. This review discusses current implementation protocols, proposed mechanisms of action, clinical efficacy, and safety profile of the ketogenic diet in epilepsy in light of the existing literature.

Keywords: Dietary treatment, Epilepsy, Ketogenic diet

1. GİRİŞ

Epilepsi, dünyada her yaştan yaklaşık 50 milyon insanı etkileyen ciddi bir nörolojik bozukluktur (WHO, 2024). Sinir sistemi hastalıkları içerisinde en sık görülen 4. hastalık olup ve tekrarlayan nöbetlerle karakterize davranışsal veya motor bozukluklardır (Milligan, 2021; Fiest ve ark., 2017). Epilepsinin temel mekanizması, nöronların aşırı uyarılması ve aşırı senkronize nöronlar arasında tekrarlayan sinaptik bağlantıların oluşmasıdır (Rafli ve ark., 2023). Dünya çapında her yıl yaklaşık 5 milyon yeni epilepsi vakası teşhis edilmektedir. Yüksek gelirli ülkelerde, her yıl 100.000 kişiden 49'una epilepsi teşhisi konulduğu; düşük ve orta gelirli ülkelerde ise bu rakamın 100.000 kişide 139'a kadar çıktığı tahmin edilmektedir (WHO, 2024). Ülkemizde ise aktif epilepsi tanısı alan 750 bin kişi olduğu belirtilmektedir (Balal ve ark., 2017).

Epilepsi hastalarının çoğu bir ya da birden fazla anti-epileptik ilaç (AEİ) ile tedaviye iyi yanıt verip nöbetler kontrol altına alınsa da hem yetişkinlerin hem de çocukların yaklaşık %30'u

AEİ'lere yeterli yanıt vermemektedir. Ayrıca uygun şekilde seçilmiş ve tolere edilebilen iki AEİ'nin yeterli denemelerine rağmen nöbetlerin kontrolü sağlanamamaktadır (Martin-McGill ve ark., 2020; Lyons ve ark., 2020). Çocuklarda, ergenlerde ve yetişkinlerde ilaca dirençli epilepsiyle ilişkili sorunlar, çok sayıda hastanın tekrar tekrar hastaneye yatırılmasına neden olmaktadır. Kontrol altına alınamayan epilepsiyle yaşamak, epilepsi hastalarının ve bakım verenlerinin yaşam kalitesini olumsuz etkiler (Ułamek-Kozioł ve ark., 2019). Mümkün olan durumlarda, ilk düşünülmesi gereken seçenek cerrahi tedavidir, ancak tüm hastalar cerrahi tedaviye uygun değildir. Bu nedenle farmakolojik olmayan tedaviler (vagus sinir stimülasyonu), palyatif cerrahi ve diyet tedavileri gibi alternatif tedavi yöntemlerinin uygulanabilir olup olmadığının araştırılması gerekmektedir (Sourbron ve ark., 2017; Martin ve ark., 2016).

Ketojenik diyet (KD), iki AEİ kullanılmasına rağmen nöbet kontrolü sağlanamayan hastalar için umut vadeden, 1920'li yıllardan beridir kullanılan tıbbi olarak kanıtlanmış farmakolojik olmayan bir tedavidir (Newmaster ve ark., 2022). KD; yüksek yağ, yeterli protein ve düşük karbonhidrat içeren bir diyettir. Ayrıca AEİ'lere kıyasla potansiyel olarak daha az yan etkisi vardır (Liu ve ark., 2019). Temel etki mekanizması, beyinde keton cisimcikleri ve yağ asitlerinin metabolizmasına dayanır; vücudun yağdan keton üretmesini ve ketonları ana enerji kaynağı olarak kullanmasını sağlar (Díez-Arroyo ve ark., 2024; Lyons ve ark., 2020).

Klasik ketojenik diyet, yağlar ve karbonhidratlar ile proteinler arasındaki orana göre hesaplanır. En yaygın oran 3:1 veya 4:1'dir; bu da enerjinin %90'ının yağdan, %10'unun ise karbonhidrat ve proteinlerin toplamından geldiği anlamına gelir (Sampaio, 2016). Zamanla, hastaların tedaviye uyumunu artırmak ve olumsuz yan etkileri azaltmak amacıyla, tedaviyi daha esnek ve kabul edilebilir hale getirmek için alternatif ketojenik diyet çeşitleri geliştirilmiştir (Operto ve ark., 2020). Bunlar, klasik ketojenik diyet (KKD), orta zincirli trigliserit (MCT- Medium Chain Trygliseride) diyeti, modifiye atkin diyeti (MAD) ve düşük glisemik indeksli tedavidir (LGI- Low Glycemic Index) (Lyons ve ark., 2020).

Ketojenik diyetin epilepsi hastalarında nasıl etki ettiği tam olarak bilinmemektedir, ancak ketozun serebral enerjiyi artırdığı, uyarıcı ve engelleyici nörotransmitterleri değiştirerek nöbetleri azalttığı ve mitokondriyal katılım yoluyla nöronal enerji metabolizmasını iyileştirdiği düşünülmektedir (Smith ve ark., 2015). Güncel görüşler, kontrendikasyon olmadığı sürece ketojenik diyetin farmakolojik tedaviye dirençli epilepsili hastaların tedavisinde son çare olarak değil, erken dönemde değerlendirilmesi gerektiği yönündedir (Wang & Lin, 2013). Birçok dirençli epilepsi hastası için, diyet tedavisi, nöbet sıklığında önemli bir azalma ile yaşam

kalitesini iyileştirmeyi vaat etmektedir. Bu nedenle, şu anda ketojenik diyetin dünya çapında kullanımında bir artış gözlemlenmektedir. Bu diyetin başarılı bir şekilde uygulanması, sağlık ekibinin, sosyal ve eğitim sisteminin ve nihayetinde ailenin aktif desteğine bağlıdır. Ayrıca KD, kısıtlayıcılığı ve yan etkileri nedeniyle sıkı diyet ve tıbbi kontrol gerektirmektedir (Ułamek-Kozioł ve ark., 2019).

Epilepsi için ketojenik diyetin etkinliği ve güvenliği üzerine odaklanan çeşitli çalışmalar yapılmış olup diyetin etkinliğine dair iyi kanıtlar sunulmuştur. Rezaei ve ark. 3 ay, 6 ay ve 12 ay sonra nöbet azalma oranlarını göstermiş ve KKD'yi MAD ile karşılaştırarak, çocukların sırasıyla %52 ve %34'ünün nöbet sıklığında ve %50'sinin nöbet sayısında azalma gösterdiğini bildirmiştir (Rezaei ve ark., 2019;22:317–334.). Lyons ve ark. çocukların yaklaşık %60'ında %50'den fazla nöbetlerde azalma gösterdiğini ve %33'ünün nöbet geçirmediğini bildirmiştir (Lyons ve ark., 2020). Martin-McGill ve ark. tarafından yapılan çalışmada, nöbetlerde %50-60 oranında azalma olduğu görülmüştür (Martin-McGill ve ark., 2020). Bir diğer çalışmada, ketojenik diyetin %60'ın üzerinde etkin olduğu ve yaklaşık %35 oranında bir nöbet yokluğu bildirilmiştir (Prezioso ve ark., 2018). Levy ve ark., hastaların %38'inde nöbetlerde %50'lik bir azalma bildirmiştir (Levi ve ark., 2012). São Paulo Üniversitesi'nde ilaç dirençli epilepsisi olan çocuklarda ketojenik diyetin etkinliğini ve toleransını değerlendirmek için yapılan çalışmada; 1 yıl içinde, ketojenik diyete devam edenlerin %55'inde, %70'inde nöbet kontrolünün >%75, %25'inde nöbet kontrolünün %50-75 aralığında ve %2,5'inde nöbet kontrolünün <%50 olduğu belirlenmiştir (Sampaio, 2016). Yetişkin epilepsi hastalarında KD etkinliğini değerlendiren bir meta- analizde, bu diyetin yetişkinlerde dirençli epilepside umut vadeden bir tamamlayıcı tedavi olduğunu ve genel etkinliğinin %42 olduğunu göstermektedir. Genel uyumluluk oranı ise %45 ile nispeten düşük olarak tespit edilmiştir. Ayrıca, KKD'nin yetişkinlerde MAD'den daha etkili ancak daha az tolere edilebilir olduğunu ortaya koymuştur (Ye ve ark., 2015). Epilepsi hastalarında uyanıklık (alertness) incelenen çalışmalarda, ketojenik diyetin hastaların %51,5'inde uyanıklıkta iyileşme sağladığı bulunmuştur (Alqahtani & Mahmoud, 2016; Thompson ve ark., 2017; Vaisleib ve ark., 2004; Kossoff ve ark., 2004). Ketojenik diyetin konsantrasyon üzerine etkisini incelendiği çalışmalarda hastaların %86,4'ünde iyileşme saptamıştır (Gumus ve ark., 2015; Sirven ve ark., 1999; Schoeler ve ark., 2014).

2. SONUÇ ve ÖNERİLER

Bu derlemede epilepsi hastalarında güncel bir tedavi olan ketojenik diyetin etkileri tartışılmıştır. Sonuç olarak AEİ kullanımına rağmen nöbet sayılarında değişim olmayan inatçı epilepsi vakalarında KD tedavisinin olumlu etkilerinin olduğu, nöbet sıklığı ve sayılarında azalmalar

olduđu görülmüştür. Ayrıca KD tedavisinin epilepsi hastalarında konsantrasyonu artırdığı ve uyanıklıkta iyileşme sağladığı da görülmüştür.

Diyet tedavisinin etkinliğini, ne kadar süre devam etmesi gerektiğini ve kesilmesinden sonra yaşanacak olan yan etkileri değerlendiren daha fazla çalışmaya ihtiyaç olduğu düşünülmektedir. Ayrıca örneklem sayısının daha fazla olduğu çalışmaların yapılması da önerilmektedir.

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ACİL SAĞLIK HİZMETLERİNDE HİZMET KALİTESİ VE HASTA MEMNUNİYETİ: KAVRAMSAL BİR DEĞERLENDİRME

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ÖZET

Acil sağlık hizmetleri, sağlık sisteminin hızlı müdahale gerektiren ve hayati öneme sahip alanlarından biridir. Acil servisler, yalnızca hastane içinde tedavi sunan birimler değil, aynı zamanda hastane öncesi sağlık hizmetleri ile koordinasyon sağlayan ve kritik durumdaki hastaların hızlı değerlendirilmesini mümkün kılan önemli bileşenlerdir. Günümüzde nüfus artışı, kronik hastalıkların yaygınlaşması, yaşlı nüfus oranının yükselmesi ve acil olmayan vakaların acil servislere başvurusu, servislerde yoğunluğun artmasına yol açmaktadır. Bu durum, hizmet kalitesi ve hasta memnuniyeti kavramlarını sağlık hizmetlerinin etkinliği açısından daha kritik hâle getirmiştir.

Bu çalışma, acil sağlık hizmetlerinde hizmet kalitesi ile hasta memnuniyeti arasındaki ilişkiyi incelemek amacıyla hazırlanmış olup, mevcut bilimsel literatürün incelenmesine dayanan literatür taraması niteliğindedir. Ulusal ve uluslararası yayınlar; acil sağlık hizmetleri, triyaj uygulamaları, ambulans sistemi, hizmet kalitesi ve hasta memnuniyeti açısından değerlendirilmiştir.

Literatür incelemesi, acil servislerin sağlık sisteminde kritik bir rol üstlendiğini ve triyaj uygulamalarının hizmet akışını düzenlemede önemli olduğunu göstermektedir. Artan hasta yoğunluğu, yatak ve personel yetersizliği ile uzun bekleme süreleri hizmet kalitesini olumsuz etkileyebilir. Hizmet kalitesi; teknik yeterlilik, iletişim, empati, güvenilirlik ve fiziksel koşulları kapsayan çok boyutlu bir yapı olarak değerlendirilmektedir. Hasta memnuniyeti ise hastaların beklentileri, deneyimleri ve sağlık çalışanlarıyla kurdukları iletişimle şekillenmektedir. Özellikle bekleme süresi, iletişim ve bilgilendirme süreçleri memnuniyeti doğrudan etkiler.

Sonuç olarak, acil servislerde hasta yoğunluğunun etkin yönetimi, bekleme sürelerinin azaltılması ve hasta odaklı hizmet anlayışının benimsenmesi, hem hizmet kalitesinin artırılması hem de hasta memnuniyetinin yükseltilmesi açısından büyük önem taşımaktadır.

Anahtar Kelimeler: Acil sağlık hizmetleri, hizmet kalitesi, hasta memnuniyeti, acil servisler, triyaj

SERVICE QUALITY AND PATIENT SATISFACTION IN EMERGENCY HEALTHCARE: A CONCEPTUAL REVIEW

ABSTRACT

Emergency health services constitute a critical component of healthcare systems, requiring rapid intervention and playing a vital role in protecting human life. Emergency departments are not only units that provide treatment within hospitals but also key elements that coordinate with pre-hospital health services and enable rapid assessment of critically ill patients. In recent years, factors such as population growth, the increasing prevalence of chronic diseases, the rising proportion of elderly individuals, and the frequent use of emergency departments for non-urgent conditions have led to increased patient density. This situation has made service quality and patient satisfaction increasingly important for the efficiency and sustainability of healthcare services.

This study aims to examine the relationship between service quality and patient satisfaction in emergency health services and is designed as a literature-based review. National and international publications addressing emergency health services, triage practices, ambulance systems, service quality, and patient satisfaction were evaluated.

The literature indicates that emergency departments play a crucial role in healthcare systems and that triage practices are particularly important for organizing service flow by prioritizing patients according to the severity of their conditions. Increasing patient density, shortages of beds and personnel, and prolonged waiting times can negatively affect service quality. Service quality is considered a multidimensional concept that includes technical competence, communication, empathy, reliability, and physical conditions. Patient satisfaction is shaped not only by the medical services provided but also by patients' expectations, previous experiences, and interactions with healthcare professionals. Waiting times, communication, and information processes are key factors that directly influence patient satisfaction.

In conclusion, effective management of patient density, reduction of waiting times, and the adoption of a patient-centered approach in emergency departments are essential for improving both service quality and patient satisfaction.

Keywords: Emergency health services, service quality, patient satisfaction, emergency departments, triage.

1. GİRİŞ

Acil sağlık hizmetleri, modern sağlık sistemlerinin en kritik bileşenlerinden biri olarak, hastaların yaşamını doğrudan etkileyen acil durumlarda hızlı ve etkin müdahale sağlamak amacıyla yapılandırılmıştır (Aydın, 2006). Acil servisler, yalnızca hastanelerin destek birimi

olmanın ötesinde, bölgesel ve ulusal sağlık hizmetleri ağının önemli bir parçasını oluşturur (Heper, 2018). Bu birimler, hastaların hayati risk taşıyan durumlarda stabilize edilmesi, uygun tedavi süreçlerinin uygulanması ve gerekirse ileri merkezlere sevk edilmesi gibi görevleri yerine getirerek sağlık sisteminin etkinliğine doğrudan katkı sağlamaktadır (Şimşek ve Ark., 2019). Hizmet kalitesi, sağlık sektöründe yalnızca teknik yeterlilikle sınırlı kalmayıp, aynı zamanda hastaların beklentilerini karşılayan bütüncül bir yaklaşımı ifade etmektedir (Yazgan, 2009). Sağlık hizmetlerinin etkinliği, hastaların deneyimleri ve memnuniyet düzeyleri ile doğrudan ilişkilidir (Çaylak, 2018).

Hasta memnuniyeti, bir sağlık kuruluşundan beklenen hizmetlerin alınması, hizmet süreçlerinin anlaşılır ve güvenli bir biçimde yürütülmesi ve bireysel ihtiyaçların dikkate alınması sonucunda oluşur (Kılıç ve Topuz, 2015). Bu nedenle, hasta memnuniyeti hem hizmetin kalitesini değerlendiren bir gösterge hem de sağlık kurumlarının sürdürülebilir başarısını belirleyen temel bir faktördür. Acil servislerde hizmet kalitesi ve hasta memnuniyeti, triyaj uygulamaları, bekleme süreleri, personel yetkinliği, iletişim süreçleri ve fiziksel koşullar gibi çok boyutlu etkenlerden etkilenmektedir (Yavuz, 2003; Durmuş, 2009). Artan hasta talebi, yoğunluk, sınırlı kaynaklar ve altyapı kısıtları, acil servislerin karşılaştığı temel sorunlar arasında yer almakta ve hizmet kalitesini olumsuz yönde etkileyebilmektedir. Bu durum, aynı zamanda hasta memnuniyetinin düşmesine ve sağlık hizmetlerinden duyulan güvenin azalmasına yol açabilmektedir (Erdem ve Ark., 2008).

Bu çalışmanın amacı, acil sağlık hizmetlerinde hizmet kalitesi ve hasta memnuniyeti arasındaki ilişkiyi inceleyerek, hizmet süreçlerinin iyileştirilmesine yönelik öneriler sunmaktır. Çalışma, hizmet kalitesinin belirleyici unsurlarını, hasta memnuniyetini etkileyen faktörleri ve acil servislerin işleyişindeki kritik noktaları ele alarak, sağlık yöneticilerine ve uygulayıcılara rehberlik edecek bilgiler sağlamayı hedeflemektedir (Bagarad, 2019).

2. ACİL SAĞLIK HİZMETLERİNDE SİSTEM YAPISI

2.1 Acil Servislerin İşlevleri

Gelişmiş sağlık sistemlerinde acil servisler, hastanenin yalnızca yardımcı birimi olarak değil, bölgesel acil sağlık hizmetleri ağının kritik bir unsuru olarak değerlendirilmektedir. Bu servisler, bağlı oldukları hastanenin türüne, kapasitesine ve hizmet verdikleri bölgenin ihtiyaçlarına göre farklı organizasyonel yapılarla sahip olabilir; ancak ortak görevleri, acil tıbbi müdahaleye ihtiyaç duyan tüm hastalara hızlı, güvenli ve etkin bir şekilde hizmet sunmaktır. Acil servisler, sadece hastane içinde tedavi sağlamakla kalmaz, aynı zamanda kritik durumdaki hastaların stabilize edilmesi, hayati risklerin kontrol altına alınması ve gerekirse uygun

merkezlere koordineli bir şekilde sevk edilmesini sağlar. Türkiye'deki yasal düzenlemeler acil servisleri, kendilerine başvuran tüm acil vakalara müdahale etmekle yükümlü kılmaktadır. Bu kapsamda acil servisler, travma, kalp krizi, solunum yetmezliği ve diğer hayati risk taşıyan durumlar dahil olmak üzere geniş bir vaka yelpazesine hizmet vermektedir.

Acil servisler, hastaneye başvuran hastaların önemli bir bölümünü karşılamakta ve özellikle yoğun travma ve kritik bakım gerektiren vakalarda sağlık sisteminin işleyişinde merkezi bir rol üstlenmektedir. Ayrıca, bu servislerin etkinliği, hem hasta sağlığı sonuçlarını iyileştirmek hem de hastanelerdeki diğer birimlerin yükünü dengelemek açısından büyük önem taşır. Acil servislerin yapı ve işleyişinde personel eğitimi, donanım kalitesi, triaj uygulamaları ve koordinasyon süreçleri gibi faktörler hizmet kalitesini doğrudan etkiler. Bu nedenle acil servisler, sağlık hizmetlerinin vazgeçilmez bir bileşeni olarak, bölgesel ve ulusal sağlık stratejilerinde öncelikli bir konumda yer almaktadır (Aydın, 2006:8).

2.2 Triyaj Uygulamaları

Trijaj, sağlık hizmetlerinde hastaların yaralanma veya hastalık durumlarının ciddiyetine ve bakım önceliklerine göre sınıflandırılmasını amaçlayan, sürekli izleme ve değerlendirme gerektiren bir süreçtir. Hastanın klinik durumu kısa sürede değişebildiği için triyaj, tek seferlik bir işlem olarak değil, gerektiğinde tekrar eden bir değerlendirme süreci olarak uygulanır. Günümüz sağlık sistemlerinde triyaj uygulamaları genellikle üç aşamada yürütülür: hastane öncesi triyaj, olay yerinde sağlık profesyoneli tarafından yapılan triyaj ve hastaneye veya acil servise başvuru sırasında gerçekleştirilen triyaj. Acil servislerde triyaj, hastaların önceliklendirilmesini sağlayarak hizmet akışının düzenlenmesinde merkezi bir rol oynar. Bu süreçte temel amaç, sınırlı kaynakları en verimli şekilde kullanarak, mümkün olan en fazla sayıda hastaya en yüksek faydayı sağlamaktır (Adıyaman ve Azizoğlu, 2025:4).

Sonuç olarak triyaj, sınırlı tıbbi kaynak ve personel durumunda, hastaların önceliklerinin belirlenmesine yönelik sistematik bir karar alma sürecidir. Temel amacı, olası en az zararlı hastaların bakımını sağlamak ve mevcut tedavi kapasitesini etkin biçimde kullanmaktır. Bu süreç, hangi hastaya hangi zamanda ve hangi tedavi olanaklarının sunulacağına ilişkin kriterlerin belirlenmesini ve uygulanmasını içerir. Triyaj uygulamaları özellikle acil servisler ve yoğun bakım ünitelerinde yaygın olarak kullanılmaktadır (Heper: 158).

2.3 Türkiye'de Ambulans Sistemi

Acil durumlarda ambulans, olay yerine en yakın istasyondan sevk edilir. Ambulans istasyonları yalnızca hasta nakli yapmakla kalmaz; 112 çağrılarını karşılar, kayıtları tutar, ilk yardım eğitimleri düzenler, hastane acil servisleriyle koordinasyonu sağlar ve afet veya toplu

yaralanma gibi özel durumlarda kurumlar arası eşgüdümü yürütür. Türkiye’de ambulans istasyonları son yıllarda ülke genelinde yaygınlaştırılmış ve kırsal alanları da kapsayacak şekilde hizmet vermeye başlamıştır. İstasyonlar hizmet kapsamına göre A, B ve C tipi olarak sınıflandırılır; A tipi yalnızca ambulans hizmeti sunarken, B tipi hem ambulans hem acil sağlık hizmeti verir ve C tipi ise belirlenen saatlerde sadece ambulans görevi üstlenir (Şimşek ve Ark.,2019:123).

2.4 Acil Servislerde Yoğunluk Sorununun Temel Dinamikleri

Acil servislerdeki aşırı yoğunluk; hasta başvurularındaki artış, personel ve yatak yetersizliği, fiziksel alanların sınırlılığı ve hizmet süreçlerindeki aksaklıklardan kaynaklanmaktadır. Nüfus artışı, yaşlı ve kronik hastalığı olan bireylerin sayısındaki yükselme ile acil olmayan vakaların acil servislere yönelmesi bu yoğunluğu artıran temel etkenlerdir. Ayrıca ağır ve çoklu hastalığı bulunan hastaların artması, tanı ve tedavi sürelerini uzatarak acil servislerde kalış süresini artırmaktadır.

Bu durum bekleme sürelerinin uzamasına, hasta bakımında gecikmelere ve hasta memnuniyetinin azalmasına yol açmaktadır. Aşırı yoğunluk, tanı ve tedavide gecikmeler nedeniyle hasta güvenliğini tehdit etmekte, tıbbi hata riskini artırmakta ve sağlık çalışanlarının iş yükünü ağırlaştırmaktadır. Sonuç olarak acil servis yoğunluğu, hem hizmet kalitesini hem de hasta deneyimini olumsuz etkileyen önemli bir sağlık sistemi sorunu olarak değerlendirilmektedir (Durmuş, 2009:6).

3. HİZMET KALİTESİ KAVRAMININ TEORİK TEMELİ

3.1 Sağlık Sektöründe Hizmet Kalitesi

Kalite, bir ürün ya da hizmetin sahip olduğu nitelikleri ve kullanıcı tarafından algılanan değerini ifade eden, öznel yönü güçlü bir kavramdır. Bireylerin kalite algısı; kültürel yapı, eğitim düzeyi ve yaşam koşullarına bağlı olarak farklılık göstermektedir. Günümüzde kalite yalnızca ürünle sınırlı olmayıp hizmet, süreç, insan kaynağı ve yönetim gibi birçok unsuru kapsayan çok boyutlu bir yapı olarak ele alınmaktadır.

Hizmet sektöründe kalite, müşteri beklentilerinin karşılanması, hizmetin eksiksiz ve hatasız sunulması ve müşteri memnuniyetinin sağlanmasıyla doğrudan ilişkilidir. Hizmetlerin soyut yapısı nedeniyle kalite, yoğunlukla hizmet öncesi beklentiler ile hizmet sırasında ve sonrasında oluşan algıların karşılaştırılması yoluyla değerlendirilmektedir. Bu nedenle algılanan hizmet kalitesi, hizmet kalitesinin ölçümünde temel bir yaklaşım olarak kabul edilmektedir (Arısoy, 2017: 1083).

Artan rekabet ve maliyet baskıları, sağlık işletmelerinde hizmet kalitesini önemli bir konu hâline getirmiştir. Sağlık hizmet kalitesi, sağlık işletmelerinin başarısında hasta tatmini kadar teknik yeterliliği de kapsayan çok boyutlu bir kavramdır. Yapılan araştırmalar, yalnızca hasta memnuniyetine odaklanan hizmet anlayışının medikal ihtiyaçları geri planda bırakabildiğini, sadece teknik tanı ve tedaviye odaklanan yaklaşımların ise hastaların istek ve beklentilerini ihmal edebildiğini göstermektedir. Bu nedenle sağlık işletmeleri, bilimsel norm ve standartlara uygun tanı ve tedavi süreçlerini uygularken, hastaların sosyal, kültürel ve psikolojik beklentilerini de göz önünde bulundurmalıdır. Günümüzde kesin bir tanımı bulunmamakla birlikte sağlık hizmet kalitesi, teknik kalite ile hizmet sunumunda hasta beklentilerinin birlikte karşılanması olarak değerlendirilmektedir (Yazgan, 2009:52).

3.2 Sağlıkta Hizmet Kalitesi Boyutları

Kalite, işletmelerin rekabet gücünü artıran ve müşteri memnuniyetini doğrudan etkileyen temel bir unsurdur. Hizmet kalitesi, müşterilerin beklentilerinin karşılanması ve zamanında, güvenilir şekilde hizmet sunulmasıyla ilişkilidir. Etkili iletişim, müşterinin ihtiyaçlarını doğru anlama, hizmetin uygun zamanda verilmesi ve güvenli bir şekilde sunulması hizmet kalitesinin önemli bileşenleridir. Ayrıca hizmet sunumunda süreklilik, müşteri beklentileriyle uyum ve kullanılan araçların yeterliliği kalite algısını etkilemektedir. Hizmet kalitesi; güvenilirlik, hız, nezaket, erişilebilirlik ve verimlilik gibi birçok boyuttan oluşan çok yönlü bir yapıya sahiptir ve bu boyutlar müşteri memnuniyetinin temelini oluşturmaktadır (Biçer ve Yurtsal, 2021:753-754). Hizmet kalitesi, çok boyutlu bir kavram olup yalnızca fiziksel ve maddi unsurlarla sınırlı değildir; hizmet sunumunda görev alan çalışanların tutum ve davranışları da kalite algısını önemli ölçüde etkilemektedir. Literatürde güvenilirlik, güvence ve empati gibi insan odaklı faktörlerin hizmet kalitesinin temel belirleyicileri olduğu vurgulanmaktadır. Grönroos hizmet kalitesini teknik kalite, fonksiyonel kalite ve işletme imajı boyutlarıyla açıklarken; Lehtinen ve Lehtinen fiziksel kalite, firma kalitesi ve etkileşim kalitesi ayrımını yapmaktadır. Parasuraman ve arkadaşları ise hizmet kalitesini fiziksel özellikler, güvenilirlik, heveslilik, güven ve empati olmak üzere beş temel boyut altında ele alarak, hizmet kalitesinin bütüncül bir yapı sergilediğini ortaya koymaktadır (Şahinli ve Tarım, 2020:3).

3.3 Sağlık Sektöründe Hizmet Kalitesi Ölçüm Modelleri

Sağlık sektöründe hizmet kalitesinin ölçümü için geliştirilen yaklaşımlar, hastaların beklenti ve algılarına, hizmet performansına ve hizmetin farklı boyutlarına odaklanmaktadır. Başlıca noktalar şu şekilde özetlenebilir:

- SERVQUAL, hizmet kalitesini hastaların beklentileri ile algıladıkları performans arasındaki fark üzerinden ölçen, en yaygın kullanılan ölçektir.
- Beş temel boyuta (somut özellikler, güvenilirlik, karşılık verebilme, güvence, empati) dayanır.
- SERVPERF, SERVQUAL'a alternatif olarak geliştirilmiş olup yalnızca performans algısını esas alır. Birçok araştırmada daha geçerli ve etkili sonuçlar verdiği belirtilmiştir.
- Ağırlıklı modeller (Ağırlıklı SERVQUAL ve Ağırlıklı SERVPERF), performans ve/veya beklentileri hastaların verdikleri önem dereceleriyle çarpılarak kaliteyi ölçmektedir.
- DINESERV, SERVQUAL'ın restoran hizmetlerine uyarlanmış hâlidir ve hizmet kalitesinin sürekli ölçümünü amaçlar.
- Çeşitli araştırmacılar (Cowling & Newman, Johnston, Lassar, Bahia & Nantel, Oppewal & Vriens) SERVQUAL'a eleştiriler getirerek, hizmet kalitesinin tek bir ölçekle ölçülemeyeceğini savunmuş ve farklı boyutlar ile alternatif modeller geliştirmiştir.
- Genel olarak çalışmalarda güvenilirlik, hizmet kalitesinin en önemli boyutu olarak öne çıkmakta; bunu karşılık verebilme, empati ve somut özellikler izlemektedir.

Sağlık sektöründe hizmet kalitesinin ölçümünde tek bir yöntem yerine, hizmetin niteliğine ve araştırma amacına uygun birden fazla yaklaşımın birlikte kullanılması daha sağlıklı ve geçerli sonuçlar sağlamaktadır (Yazgan, 2009:56-61).

3.4 Türkiye Acil Servis Kalite Standartları

Türkiye'de acil sağlık hizmetleri, Sağlık Bakanlığı tarafından belirlenen hastane kalite standartlarına göre sunulmaktadır. Bu standartlar; acil servise erişim, fiziksel koşullar, yönlendirme sistemleri, hizmet süreçleri, ekipman yeterliliği ile hasta ve çalışan güvenliğini kapsamaktadır. Acil servislerde triaj, hasta kabul, müşahede, konsültasyon, laboratuvar ve görüntüleme hizmetleri belirli kurallar çerçevesinde yürütülmekte; gerekli ilaç ve tıbbi malzemelerin hazır bulundurulması zorunlu tutulmaktadır. Ayrıca hasta mahremiyeti, hijyen, güvenli ilaç uygulamaları ve tüm bireylere eşit sağlık hizmeti sunulması kalite standartlarının temelini oluşturmaktadır (Altındış ve Ünal, 2017:53).

4. HASTA MEMNUNİYETİ PERSPEKTİFİ

4.1 Memnuniyetin Tanımı ve Hasta Memnuniyeti

Memnuniyet, çok boyutlu ve çeşitli faktörlerden etkilenen bir kavramdır. Bu faktörler arasında bireyin yaşam tarzı, gelecek beklentileri, geçmiş deneyimleri ve kişisel değerleri yer alırken, toplumsal normlar ve değerler de önemli bir rol oynamaktadır. Hasta memnuniyeti ise

genellikle, “hastanın sağlık kuruluşundan beklediği her şeyin toplamı” şeklinde tanımlanabilir. Karşılanan beklentiler arttıkça hasta memnuniyeti de yükselmekte olup, aynı tıbbi hizmeti alan farklı kişiler arasında farklılık gösterebileceği gibi, aynı hastanın farklı zamanlarda yapılan başvurularında da değişiklik gösterebilir (Çaylak, 2018:9).

Hasta memnuniyeti, bireyin sağlık hizmeti alma kararı ile başlayan süreçte, hizmeti araştırması, bulması, erişmesi ve kullanması sırasında yaşadığı deneyimlerin ve elde ettiği faydaların beklentileriyle karşılaştırılması sonucu ortaya çıkan tatmin düzeyidir. Başka bir ifadeyle, sağlık kurumlarında kalite göstergesi olarak kabul edilen hasta memnuniyeti, hastaların beklenti ve taleplerinin mümkün olan en iyi şekilde karşılanması anlamına gelir (Kılıç ve Topuz, 2015:82). Hasta memnuniyeti, bireylerin aldıkları sağlık hizmetlerinden elde ettikleri yararlar, karşılaştıkları zorluklardan kurtulma durumu, hizmetten bekledikleri performans ve hizmetin sunum biçiminin sosyo-kültürel değerlerle uyumuna bağlı olarak şekillenen çok boyutlu bir kavramdır. Bu değerler arasında kişinin ve ailesinin kültürel özellikleri, sosyal statüsü, yaşam biçimi, alışkanlıkları, zevkleri ve önyargıları yer alır. Hasta memnuniyeti, birden fazla değişkenin etkileşimi sonucunda ortaya çıkmakta ve özellikle hastanın hizmeti almadan önceki beklentileri ile hizmeti deneyimledikten sonraki algıları arasındaki fark ile belirlenmektedir. Bu nedenle hasta memnuniyeti, hastanın sağlık kuruluşundan ne beklediği ile ne bulunduğu arasındaki psikolojik tatmin düzeyi olarak tanımlanabilir. Ayrıca, hasta memnuniyeti, sağlık hizmetlerinin kalitesinin önemli göstergelerinden biri olarak değerlendirilmektedir. Araştırmalar genellikle hizmet kalitesi ile hasta memnuniyeti arasındaki bağlantıyı incelemekte; ancak bu iki kavram arasındaki ilişkinin her zaman aynı yönde veya aynı düzeyde gerçekleşmediği de gözlemlenmektedir (Erdem ve ark., 2008:97).

4.2 Hasta Memnuniyeti Ölçüm Yöntemleri

Hasta memnuniyetine yönelik araştırmalar nitel (kalitatif) ve nicel (kantitatif) olmak üzere iki grupta incelenmektedir:

Nitel araştırmalar, hastaların sağlık hizmeti sürecine ilişkin deneyimlerini, algılarını ve duygularını derinlemesine anlamayı amaçlar. Bu kapsamda odak grup görüşmeleri, gözlem, bireysel görüşmeler, ses ve görüntü kayıtları ile gizli müşteri uygulamaları kullanılmaktadır. Odak grup görüşmeleri, bir moderatör eşliğinde küçük hasta gruplarıyla yürütülmekte ve hizmet sunumunun geliştirilmesine yönelik önemli geri bildirimler sağlamaktadır. Ancak katılımcıların birbirinden etkilenmesi yöntemin sınırlılığdır.

Nicel araştırmalar ise hasta memnuniyetinin ölçülmesine yönelik yapılandırılmış veri toplama tekniklerine dayanır. Yüz yüze, telefonla veya posta yoluyla uygulanan anketler bu gruptaki

temel yöntemlerdir. Anketler; sağlık kuruluşunun fiziki koşulları, hizmet sunum süreci, insan kaynağı ve sunulan hizmetin hasta açısından yararını değerlendirecek şekilde hazırlanmalıdır. Posta ve telefon anketleri pratik olmakla birlikte, yanıtlamama ve yanlış anlama gibi riskler içermektedir (Budak, 2015:33)

4.3 Acil Serviste Hasta Memnuniyeti ve Etkileyen Faktörler

Acil servisler, hastaların hastane ile ilk temas noktası olması nedeniyle hasta memnuniyeti açısından önemli bir yere sahiptir. Ancak yoğunluk, uzun bekleme süreleri, iletişim sorunları ve fiziksel koşullar hasta deneyimini olumsuz etkileyebilmektedir. Hasta memnuniyeti, acil servis hizmet kalitesinin temel göstergelerinden biri olup, hastaların tedaviye uyumunu, sağlık sonuçlarını ve gelecekteki sağlık hizmeti tercihlerine yön vermektedir. Aynı zamanda sağlık çalışanlarının iş doyumunu ve hizmet sunumunun sürdürülebilirliği açısından da önem taşımaktadır. Aşırı kalabalıklaşma ise hasta güvenliğini ve memnuniyetini azaltarak olumsuz klinik sonuçlara yol açabilmektedir (Yılmaz, 2019:28-30).

Acil servisler, hastanenin performansını ve imajını doğrudan yansıtan birimlerdir. Artan hasta talebi ve yoğunluk, servislerde kalabalıklaşmaya yol açarken, bekleme süreleri hasta memnuniyetini doğrudan etkileyen önemli bir faktör olarak öne çıkmaktadır. Hasta memnuniyeti; sağlık çalışanlarının iletişim ve empati düzeyi, hizmetin teknik ve fiziksel koşulları ile bilgilendirme süreçlerinden etkilenir. Ayrıca hastaların demografik özellikleri ve sağlık durumu, memnuniyet algısını şekillendirir. Etkin bir acil servis yönetimi, bekleme sürelerini azaltarak, hizmet kalitesini artırmakta ve hastaların deneyimlerini olumlu yönde etkilemektedir. Bu nedenle acil servis personelinin iletişim ve hasta odaklı hizmet becerileri konusunda eğitilmesi, memnuniyetin yükseltilmesi ve hizmet etkinliğinin sağlanması açısından kritik öneme sahiptir (Yavuz, 2003:18).

5. HİZMET KALİTESİ – HASTA MEMNUNİYETİ ETKİLEŞİMİ

5.1 Literatürde Tanımlanan İlişkiler

Hasta memnuniyeti, sağlık hizmetlerinde kalitenin en önemli göstergelerinden biridir. Hizmet kalitesi ile hasta memnuniyeti farklı kavramlar olsa da, birbirleriyle yakından ilişkilidir. Günümüzde bilim ve teknolojiye gelişmeler, insanların sağlık hizmetlerinden beklentilerini artırmış ve kaliteli hizmet sunan hastaneleri daha ön plana çıkarmıştır. Bu durum, sağlık sektöründe rekabetin artmasına neden olmuştur. Sağlık kurumları, hasta memnuniyetini sağlayabilmek için kaliteli ve etkili hizmet sunmak zorundadır. Sunulan hizmetin kalitesi yükseldikçe hastaların memnuniyet düzeyi de artmakta, kalite düştüğünde ise memnuniyetsizlik ortaya çıkmaktadır. Bu nedenle hizmet kalitesi ve hasta memnuniyeti

birbirini etkileyen önemli unsurlardır. Ayrıca hizmet kalitesi, hasta memnuniyetiyle birlikte müşteri sadakati ve kurumların başarısı üzerinde de etkili olmaktadır. Bu bağlamda, sağlık hizmetlerinde kalite, kurumların hedeflerine ulaşmasında önemli bir rol oynamaktadır (Bagarad, 2019:4).

Hasta memnuniyeti, sağlık hizmetlerinde sunulan hizmet kalitesinin geliştirilmesinde belirleyici bir unsurdur. Hastaların beklentileri, önceki deneyimleri ve geri bildirimleri, sağlık kurumlarının hizmet sunum süreçlerini şekillendirmede önemli bir rol oynamaktadır. Hasta memnuniyeti; bireysel özellikler, geçmiş deneyimler, çevresel etkenler ve hizmete ilişkin algılar doğrultusunda oluşmaktadır. Sağlık kurumlarının sürdürülebilir başarısı açısından hasta memnuniyetinin kurumsal düzeyde benimsenmesi gerekmektedir. Bu doğrultuda, hasta odaklı bir hizmet anlayışının tüm çalışanlar tarafından benimsenmesi, hizmet süreçlerinin düzenli olarak ölçülmesi, analiz edilmesi ve iyileştirilmesi önem taşımaktadır. Bununla birlikte, hizmet kalitesi ile hasta memnuniyeti arasında her zaman doğrudan ve birebir bir ilişki bulunmayabilir. Hizmetin maliyeti, algılanan değer ve hastaların beklenti düzeyi, memnuniyet üzerinde belirleyici olabilmektedir. Dolayısıyla hasta memnuniyeti, yalnızca sunulan hizmetin kalitesine değil, aynı zamanda hastaların bilişsel ve duygusal değerlendirmelerine dayanan çok boyutlu bir kavramdır (Kuzhan, 2009:60-61).

5.2 Hizmet Kalitesini Artırmak İçin Gereken Unsurlar

Gelişmekte olan sağlık kuruluşlarında hizmet kalitesini artırmak için hasta odaklı bir yaklaşım benimsenmesi kritik öneme sahiptir. Kuruluşlar, hastaların ihtiyaçlarını anlamalı, beklentilerine saygı göstermeli ve sorunlarına etkili çözümler sunabilmelidir. Bu sorumluluk yalnızca yöneticilere değil, tüm çalışanlara aittir. Yönetimin rolü, kaliteye odaklanan bir liderlik sergilemek, çalışanları motive etmek ve sürekli iyileştirme bilincini kazandırmaktır. Ayrıca çalışanlar arasında sağlıklı iletişim, güçlü bir örgüt kültürü ve işbirliği, hizmet kalitesinin sürdürülebilir bir şekilde yükseltilmesini destekleyen temel unsurlardır (Sevimli, 2006:19).

SONUÇ

Acil sağlık hizmetleri, sağlık sisteminin en kritik ve dinamik alanlarından biri olup, hizmet sunumunun niteliği doğrudan hasta yaşamı ve sağlık sonuçlarıyla ilişkilidir. Bu çalışmada acil sağlık hizmetlerinin sistem yapısı, hizmet kalitesi kavramı ve hasta memnuniyeti perspektifi bütüncül bir yaklaşımla ele alınmış; hizmet kalitesi ile hasta memnuniyeti arasındaki etkileşim kuramsal ve uygulamaya dönük boyutlarıyla incelenmiştir.

Acil servisler, yalnızca hastane içi hizmet sunan birimler değil, aynı zamanda hastane öncesi sağlık hizmetleriyle entegre çalışan, bölgesel ve ulusal sağlık sisteminin temel yapı taşlarıdır.

Triyaj uygulamaları, ambulans sistemi ve acil servislerin organizasyonel yapısı, hizmetin hızlı, güvenli ve etkili bir şekilde sunulmasında belirleyici rol oynamaktadır. Ancak artan hasta başvuruları, personel ve yatak yetersizliği ile fiziksel altyapı sorunları, acil servislerde yoğunluk problemini beraberinde getirmekte; bu durum hem hizmet kalitesini hem de hasta memnuniyetini olumsuz etkilemektedir.

Hizmet kalitesi, sağlık sektöründe yalnızca teknik yeterlilikle sınırlı olmayan, hasta beklentileri, algıları ve deneyimleriyle şekillenen çok boyutlu bir kavramdır. Özellikle acil servislerde hizmetin soyut, hızlı ve stresli yapısı, algılanan hizmet kalitesinin önemini artırmaktadır. Hasta memnuniyeti ise hizmet kalitesinin en önemli çıktılarında biri olup, hastaların beklentileri ile aldıkları hizmet arasındaki uyum düzeyiyle doğrudan ilişkilidir. Bu bağlamda, hizmet kalitesindeki iyileşmelerin hasta memnuniyetini artırdığı; hasta memnuniyetinin de sağlık kurumlarının imajı, tercih edilirliliği ve sürdürülebilir başarısı üzerinde etkili olduğu görülmektedir.

Acil servislerde hasta memnuniyetini etkileyen faktörler arasında bekleme süreleri, sağlık çalışanlarının iletişim ve empati düzeyi, bilgilendirme süreçleri, fiziksel koşullar ve hasta güvenliği ön plana çıkmaktadır. Yoğunluk nedeniyle yaşanan gecikmeler ve iletişim sorunları, hasta deneyimini olumsuz yönde etkileyerek memnuniyet düzeyini düşürebilmektedir. Bu nedenle acil servis yönetiminde yalnızca klinik süreçlere değil, hasta odaklı hizmet anlayışına da öncelik verilmesi gerekir.

Sonuç olarak, acil sağlık hizmetlerinde hizmet kalitesi ile hasta memnuniyeti birbirini tamamlayan ve karşılıklı olarak etkileyen iki temel unsurdur. Hizmet kalitesinin artırılması; etkin yönetim, yeterli insan kaynağı, güçlü iletişim, sürekli eğitim ve sistematik kalite ölçüm ve iyileştirme çalışmalarıyla mümkün olmaktadır. Hasta memnuniyetinin artırılmasına yönelik geliştirilecek stratejiler, hem sağlık hizmetlerinin etkinliğini yükseltecek hem de acil servislerin sağlık sistemi içindeki işlevsel rolünü güçlendirecektir. Bu doğrultuda, acil sağlık hizmetlerinde kalite odaklı ve hasta merkezli yaklaşımların yaygınlaştırılması, sağlık sisteminin genel performansına önemli katkılar sağlayacaktır.

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TÜRKİYE VE MALEZYA ARASINDAKİ TİCARETİN GELİŞİMİNDE SERBEST TİCARET ANLAŞMASININ ROLÜ

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ÖZET

Küresel ekonomik entegrasyonun derinleştiği günümüzde, Serbest Ticaret Anlaşmaları (STA) ulus devletlerin jeoekonomik önceliklerini şekillendiren proaktif dış ticaret enstrümanlarına dönüşmüştür. Bu çalışma, Türkiye'nin Asya-Pasifik açılımının stratejik bir halkasını teşkil eden ve 1 Ağustos 2015 tarihinde yürürlüğe giren Türkiye-Malezya Serbest Ticaret Anlaşması'nın (TM-STA) makroekonomik ve sektörel yansımalarını ampirik bir perspektifle analiz etmeyi amaçlamaktadır. 2013-2025 dönemini kapsayan veriler ışığında gerçekleştirilen incelemede; tarafların gayrisafi yurt içi hasıla (GSYİH) gelişimleri, dış ticaret hacimleri ve Geniş Ekonomik Kategoriler (BEC) bazlı ticaret kompozisyonları mukayeseli olarak ele alınmıştır.

Araştırma bulguları, TM-STA'nın yürürlüğe girmesini takiben ikili ticarete Türkiye aleyhine belirgin bir asimetric genişleme yaşandığını ortaya koymaktadır. Özellikle hammadde ve ara malı kategorilerinde gözlemlenen ithalat ivmesi, Türk imalat sanayisinin Malezya menşeli endüstriyel girdilere (demir-çelik, palm yağı, alüminyum vb.) yönelik yapısal bağımlılığını teyit etmektedir. Ancak söz konusu dış ticaret açığı, salt bir refah sızıntısından ziyade, üretim süreçlerine eklenmiş stratejik bir girdi tedariği ve "fonksiyonel entegrasyon" modeli olarak değerlendirilmelidir. Çalışmada ayrıca, 1 Ağustos 2024 itibarıyla yürürlüğe giren Hizmetler ve Yatırımlar Protokolü'nün sunduğu derinleşme fırsatları ile güncel mevzuat değişiklikleri irdelenmiştir. Sonuç olarak, Türkiye'nin bu asimetric yapıdan sürdürülebilir bir katma değer üretebilmesi için lojistik, müteahhitlik ve yüksek katma değerli ürün ihracatına odaklanan proaktif bir ticaret diplomasisi izlemesi gerektiği vurgulanmaktadır.

ANAHTAR KELİMELELER

Türkiye-Malezya STA, Dış Ticaret Asimetrisi, Ara Malı Bağımlılığı, Asya-Pasifik Ticareti, Sektörel Analiz.

THE ROLE OF THE FREE TRADE AGREEMENT IN ENHANCING TRADE RELATIONS BETWEEN TÜRKİYE AND MALAYSIA

ABSTRACT

In today's era of deepening global economic integration, Free Trade Agreements (FTAs) have evolved into proactive foreign trade instruments that shape the geoeconomic priorities of nation-states. This study aims to analyze, from an empirical perspective, the macroeconomic and sectoral repercussions of the Türkiye-Malaysia Free Trade Agreement (TM-FTA), which entered into force on August 1, 2015, constituting a strategic link in Türkiye's Asia-Pacific initiative. In the examination conducted in light of data covering the 2013-2025 period, the gross domestic product (GDP) developments of the parties, their foreign trade volumes, and their trade compositions based on Broad Economic Categories (BEC) are comparatively addressed.

The research findings reveal that following the entry into force of the TM-FTA, a distinct asymmetric expansion occurred in bilateral trade to the detriment of Türkiye. The import momentum observed, particularly in the raw material and intermediate goods categories, confirms the structural dependence of the Turkish manufacturing industry on industrial inputs of Malaysian origin (iron and steel, palm oil, aluminum, etc.). However, the aforementioned foreign trade deficit should be evaluated as a strategic input supply integrated into production processes and a model of "functional integration," rather than merely a welfare leakage. Furthermore, the study scrutinizes the deepening opportunities presented by the Protocol on Services and Investments, which entered into force as of August 1, 2024, alongside current legislative amendments. Consequently, it is emphasized that for Turkey to generate sustainable value-added from this asymmetric structure, it must pursue proactive trade diplomacy focusing on logistics, contracting services, and the export of high value-added products.

KEYWORDS

Turkey-Malaysia FTA, Foreign Trade Asymmetry, Intermediate Goods Dependency, Asia-Pacific Trade, Sectoral Analysis.

1.Giriş

Küresel ekonomik entegrasyonun derinleştiği günümüzde, ulusal ticaret politikaları ve Serbest Ticaret Anlaşmaları (STA), uluslararası rekabetin temel belirleyicileri konumuna gelmiştir. Bu mekanizmalar, yalnızca mal ve hizmet akışını düzenlemekle kalmayıp, küresel piyasalardaki jeoekonomik güç dengelerini de yeniden yapılandırmaktadır. Özellikle gelişmekte olan ekonomiler için STA'lar; ihracat hedeflerine ulaşılmasında ve sürdürülebilir büyümenin tesis edilmesinde stratejik bir dış ticaret enstrümanı olarak öne çıkmaktadır.

Serbest ticaret anlaşmaları, taraf ülkeler arasındaki tarifeleri ve tarife dışı engelleri azaltarak veya tamamen kaldırarak ticareti geliştirmeyi amaçlayan uluslararası anlaşmalardır. Bu anlaşmalar, kaynakların daha etkin bir şekilde dağılmasına, uzmanlaşmaya ve dolayısıyla verimlilik artışına olanak tanıyarak ekonomik büyüme için teşvik edici niteliğe sahiptir. Serbest ticaret anlaşmaları firmaların daha geniş pazarlara erişimini sağlayarak ihracat potansiyelini artırmakta ve tüketicilere daha çeşitli ve uygun fiyatlı ürünler sunmayı hedeflemektedir. Türkiye gibi yükselen ekonomiler açısından STA'lar, dış ticaret stratejilerinin önemli bileşenidir. Bu anlaşmalar sayesinde Türkiye, yeni pazarlara giriş, mevcut pazarlardaki payını artırma ve rekabet gücünü yükseltme fırsatına erişmektedir. Aynı zamanda, geleneksel mal ihracatının yanı sıra, lojistik, finans, danışmanlık ve mühendislik gibi hizmet sektörleri de ihracat portföyünde giderek daha fazla yer almaktadır. STA'lar, hizmet ticaretinin serbestleşmesine katkı sağlayarak bu sektörün büyüme potansiyelini desteklemektedir.

Türkiye'nin dış ticaret rejiminde STA'ların evrimi incelendiğinde, başlangıçta 1/95 sayılı Ortaklık Konseyi Kararı gereğince Avrupa Birliği'nin Ortak Ticaret Politikasına uyum sağlama zorunluluğunun hâkim olduğu görülmektedir. Bu zorunluluk doğrultusunda Türkiye; Kuzey Afrika, Ortadoğu ve Latin Amerika'daki pek çok ülkeyle, çoğu zaman AB'nin imzaladığı anlaşmaları takiben paralel STA'lar akdetmiştir. Ancak son yıllarda Türkiye'nin ticaret diplomasisi, salt bir pasif uyum sağlayıcı rolünden çıkarak kendi jeo-ekonomik öncelikleri doğrultusunda bağımsız inisiyatif alan proaktif bir karaktere bürünmüştür. Günümüz itibarıyla EFTA'dan Balkanlar'a, Latin Amerika'dan Asya-Pasifik'e uzanan geniş bir coğrafyada yürürlükte olan 24 adet STA, bu çok boyutlu vizyonun somut bir çıktısıdır.

Türkiye'nin Gümrük Birliği'nin pasif sınırlarını aşarak stratejik bir önceliklendirme yaptığı ve Asya-Pasifik bölgesine yönelik genişleyen STA ağının en kritik halkalarından birini, Türkiye ve Malezya arasında imzalanan serbest ticaret anlaşması (TM-STA) oluşturmaktadır. 1 Ağustos 2015 tarihinde yürürlüğe giren bu anlaşma, iki ülke arasındaki ticari ilişkilerin bağlarının sağlamlaşmasına katkı sağlamıştır. Dikkat çekici olan husus, bu anlaşma sayesinde Türkiye'nin, Avrupa Birliği'nden daha önce Malezya pazarına tercihli erişim olanağı elde etmiş ve küresel rekabette önemli bir ilk hareket avantajı sağlamış olmasıdır. Anlaşma ile birçok sanayi ve tarım ürünlerinde gümrük vergileri kademeli olarak sıfırlanmış, menşe kuralları belirlenmiş ve gümrük işlemlerinin kolaylaşması sağlanmıştır.

TM-STA örneği üzerinden 2015-2024 dönemine ait dış ticaret dinamikleri değerlendirilirken, anlaşmanın her iki ülke ekonomisi üzerindeki makroekonomik yansımalarını anlamak kritik bir önem taşımaktadır. Bu doğrultuda çalışma; Malezya'nın Asya-Pasifik bölgesindeki ekonomik

yapısını ve Türkiye ile olan ikili ticaret hacmindeki tarihsel gelişimi temel alarak, STA'nın yürürlüğe girmesiyle oluşan yapısal kırılmaları analiz etmektedir. Anlaşma öncesi ve sonrası dönemlere ait ihracat ve ithalat verilerindeki değişimler ile mal ticaretine konu olan başlıca sektörel kalemler incelenerek, pazar entegrasyonunun boyutu ve STA'nın Türkiye açısından doğurduğu sonuçlar somut veriler ışığında ortaya konmuştur.

Bu temel amaçlar doğrultusunda, çalışmanın ilerleyen bölümleri şu şekilde kurgulanmıştır: Çalışmanın ikinci bölümünde, serbest ticaret anlaşmalarının küresel ticaretteki yeri ve Türkiye'nin dış ticaret politikalarındaki tarihsel evrimi teorik bir çerçevede ele alınmaktadır. Üçüncü bölümde, Türkiye ile Malezya arasındaki ikili ekonomik ilişkilerin tarihsel gelişimi, yürürlüğe giren STA'nın yasal altyapısı, kapsamı ve son dönemde hizmetler ile yatırımları da içerecek şekilde genişletilen protokol güncellemeleri detaylandırılmaktadır. Dördüncü bölümde, iki ülkenin makroekonomik büyüklükleri karşılaştırılarak, STA öncesi ve sonrası döneme ait dış ticaret hacimleri, ithalat-ihracat dengeleri ve ticarete konu olan başlıca sektörel ürün grupları veriler ışığında analiz edilmektedir. Çalışmanın beşinci ve son bölümünde ise elde edilen bulgular sentezlenerek, TM-STA'nın doğurduğu asimetrik ticaret sonuçları tartışılmakta ve Türkiye'nin bu entegrasyondan sağlayacağı katma değeri maksimize edebilmesine yönelik stratejik politika önerileri sunulmaktadır.

2. Serbest Ticaret Anlaşmaları: Teorik Temeller, Tarihsel Gelişim ve Türkiye'nin Entegrasyon Süreci

Uluslararası iktisat teorisi bağlamında STA'lar, taraf ülkeler arasında mal ve hizmet ticaretine uygulanan gümrük tarifelerini, miktar kısıtlamalarını ve diğer tarife dışı engelleri karşılıklı olarak ortadan kaldırmak amacıyla akdedilen tercihli ticaret mekanizmalarıdır. Uluslararası Ticaret İdaresi (International Trade Administration, 2022) verilerine göre bu anlaşmalar, ülkelerin karşılıklı ticarete uyguladıkları vergi yüklerinden ve sınırlayıcı kotalardan korunmalarını sağlayarak dış ticaretin önündeki bariyerleri minimize etmektedir. Ancak günümüzde STA'ların kapsamı salt geleneksel mal ticaretiyle sınırlı kalmamakta; fikri mülkiyet hakları, devlet ihaleleri, rekabet politikaları ve karşılıklı yatırımların güvence altına alınması gibi derin entegrasyon konularını da içerecek şekilde genişlemektedir.

Teorik açıdan STA'ların temel hedefi, neoklasik iktisadın yapıtaşlarından olan karşılaştırmalı üstünlükler teorisi, iş bölümü ve uluslararası uzmanlaşma prensipleri aracılığıyla ticaret hacmini artırmaktır. Kalaycı (2017) tarafından da vurgulandığı üzere, daha etkin bir kaynak tahsisi arzulayan ülkeler, iç pazarlarındaki katı korumacılık kalkanlarını indirerek partner

ülkelerin üreticilerine daha geniş pazar olanakları sunma yoluna gitmektedir. Kendi aralarında bu entegrasyonu kuran ülkeler, daha geniş tüketici kitlelerine ulaşarak endüstrilerinde ölçek ekonomileri yaratma üstünlüğü elde etmektedir. Ticaret engellerinin azalması, üye ülkelerin iç piyasalarında rekabeti körükleyerek makroekonomik boyutta ciddi bir dinamizm sağlamaktadır. Hur ve Park (2012) da bu durumu destekleyerek, pazarın genişlemesi ve rekabet ortamının kızışmasının, ekonomik verimliliğin artmasına, sürdürülebilir büyümenin desteklenmesine ve sonuç olarak ülkelerin toplumsal refah düzeylerinin yükselmesine doğrudan katkı sağladığını belirtmektedir. İlgi çekici olan nokta ise, kendi aralarında tercihli bir serbestleşme düzeni kuran bu ülkelerin, söz konusu imtiyazları Dünya Ticaret Örgütü (WTO) üyesi diğer üçüncü ülkelere yaygınlaştırmaksızın aralarındaki ticareti serbestleştirmeleridir.

Dünya ticaret kapasitesindeki tarihsel artış, korumacı engelleri yıkmaya yönelik kurumsal ve uluslararası adımların doğrudan bir sonucudur. Serbest ticaretin uluslararası bir iktisadi doktrin olarak kök salması 19. yüzyıla dayanmaktadır. Ficher (1987) tarafından yapılan tarihsel analize göre, ekonomik temelleri kıtalar arası deniz ticaretine dayanan İsviçre, İtalya ve Hollanda gibi ülkeler, ekonomik yapıları gereği doğal olarak serbest ticareti destekleyici bir pozisyon almışlardır. Bu dönemin hegemonik gücü İngiltere ise, 1820 ile 1880 yılları arasında serbest ticaret politikalarını istikrarlı bir şekilde uygulamış ve Avrupa kıtasının 1870'lerden itibaren yeniden korumacılığı temel politika olarak benimsemesine rağmen serbest ticarete olan kurumsal bağlılığını sürdürmüştür. Süregelen bu katı korumacı politikaların yaratabileceği küresel refah kayıplarını ve olası yıkıcı etkilerini dizginlemek amacıyla, ülkeler zamanla ikili ve çok taraflı ticaret anlaşmalarını hayata geçirmeye başlamıştır.

Bu arayışların kurumsal bir çatı altında toplanması, II. Dünya Savaşı sonrasında 23 ülkenin bir araya gelmesiyle 1947 yılında imzalanan Gümrük Tarifeleri ve Ticaret Genel Anlaşması (GATT) ile mümkün olmuştur. Dış ticaretin serbestleşmesi adına atılan bu devasa adım, uluslararası ticareti felç eden tarife dışı engellerin ve aşırı yüksek gümrük tarifelerinin çok taraflı müzakerelerle ortadan kaldırılmasını hedeflemiştir.

Küresel ticaretteki asıl ivmelenme ve kırılma noktası ise 1980'li yıllardan sonra yaşanmıştır. Strateji ve Bütçe Başkanlığı (2025) raporlarına göre, özellikle küreselleşmenin muazzam bir hız kazandığı 1980-2008 döneminde dünya genelinde ticaret engellerinin önemli ölçüde azalması ve üretim süreçlerinin parçalanarak küresel üretim zincirlerinin meydana gelmesi, serbest ticaretin doğasını değiştirmiştir. Bu dönemde hız kazanan politikalar, ticaret kapasitesinde ve dünya ticaret hacminde kesintisiz bir artış trendi yaratmıştır. Bu yapısal

dönüşüm, 1990 yılında kurulan Dünya Ticaret Örgütü (DTÖ) ile taçlanmıştır. Kavacık (2021) tarafından da ifade edildiği üzere, GATT kapsamındaki Uruguay Turu'nun tamamlanmasının ardından ulus-devletler, katı çok taraflı müzakerelerin yavaşlığından sıyrılarak ticaretin serbestleşmesi için daha hızlı sonuç veren ikili ve bölgesel STA'ları yoğun olarak tercih etmeye başlamışlardır.

Günümüzde bu ticaret anlaşmaları mimarisi; çevresel, siyasi, ekonomik ve teknolojik değişkenlerin yönlendirdiği çok katmanlı bir yapıya bürünmüştür. Özellikle Çin'in Asya-Pasifik merkezli kurduğu ekonomik hegemonya, uluslararası ticaret sisteminin düzenini kökünden değiştiren derin sarsıntılar yaratmıştır. Çin'in bu agresif yükselişine karşı Güney Doğu Asya pazarlarına yönelik alternatif seçenek arayışları, bölgedeki ülkeleri ve küresel aktörleri son yıllarda büyük bir hızla bölgesel ve ikili STA'lar akdetmeye yöneltmiştir (Petri & Plummer, 2020).

Türkiye, dünyada meydana gelen bu serbestleşme ve küresel üretim zincirlerine entegrasyon eğilimlerine paralel olarak dış ticaret stratejisini radikal bir biçimde yeniden kurgulamıştır. 24 Ocak Kararları ile temeli atılan ve 1980 sonrasında benimsenen ihracata dayalı, dışa açık ekonomik büyüme modeli, Türkiye'nin dış ticaret hacmini maksimize etmeye odaklanan temel doktrini olmuştur. Dursun ve AYTEKİN (2022) çalışmasında detaylandırıldığı üzere, 1980'li yılların küresel serbestleşme ve finansallaşma akımlarına eklemlenen Türkiye, hızlı bir ekonomik metamorfoz geçirmiş; sermaye piyasalarının derinleşmesi, sıcak para hareketlerinin serbestisi, Türk Lirasının konvertibilitesi ve nihayetinde Gümrük Birliği gibi o dönem için yepyeni olan makroekonomik kavramlarla tanışmıştır. Elbette bu dışa açılma süreci pürüzsüz ilerlememiş; entegrasyonun getirdiği yeniliklerin yanında yaşanan sarsıcı finansal krizler ve döviz darboğazlarının yarattığı yapısal sıkıntılar, Türkiye'nin iktisadi belleğine derin izler bırakmıştır.

Buna rağmen ihracatı teşvik etmeye dayalı dışa açık stratejiden taviz verilmemiş, dış ticaretin uluslararası ticaretteki payının artırılması devletin en kritik ekonomi politikalarından biri haline gelmiştir. Doğan ve Uzun (2014) tarafından yapılan çalışmada vurgulandığı üzere, Türkiye'nin dış ticaret yapısı ağırlıklı olarak enerji, hammadde ve teknoloji yoğun ürünlerin ithalatına bağımlı bir profil çizerken; sanayi ve üretim kapasitesindeki artış bu ithalat taleplerinin boyutunu şekillendiren öncü güç olmuştur. Ülkenin belirlediği makro hedefler doğrultusunda, özellikle 2000'li yıllarda 500 milyar dolarlık ihracat vizyonuna ulaşmak amacıyla son derece agresif adımlar atılmıştır. Koçtürk ve Kocafe (2014) bu noktada, STA'ların söz konusu yüksek

ihracat hedeflerine ulaşılmada, yeni pazarlara girilmesinde ve mevcut pazar paylarının konsolide edilmesinde en kritik enstrüman olarak kullanıldığını belirtmektedir.

Türkiye'nin STA politikası ve tarihsel serüveni, tekdüze bir gelişim göstermemiş; aksine farklı dönemlerin makroekonomik ihtiyaçları ve küresel konjonktür çerçevesinde şekillenen yapısal kırılmalar yaşamıştır. Akman (2010), Yaman (2016) ve T.C. Ticaret Bakanlığı verilerinden yararlanılarak aşağıda Tablo 1'de özetlenen dönemsel ayrımlar, Türkiye'nin dış ticaret stratejisindeki dönüşümü net bir biçimde ortaya koymaktadır.

Tablo 1: Türkiye'nin STA Politikasının Tarihsel Dönüşümü

Dönem	Yaklaşık Yıllar	Ana Motivasyonlar	Tipik Anlaşma Kapsamı	Öne Çıkan Özellikler
Dışa Açılma ve İlk Adımlar Dönemi	1980-1995	İhracata dayalı büyüme, Yeni pazarlar, AB'ye hazırlık	Temelde sanayi ürünleri, Sınırlı tarım tavizleri	İlk STA deneyimleri, AB entegrasyonuna ön hazırlık
Gümrük Birliği Etkisindeki STA Politikaları	1996-2010	GB'ye uyum, Domino etkisi, Pazar erişimi	Sanayi ürünleri, Belirli tarım ürünleri	AB ile uyum zorunluluğu, Yapısal sorunlar, Ticaret hacmi artışı
Yeni Nesil STA'lar ve Kapsam Genişlemesi	2011- Günümüz	Kapsamlı entegrasyon, Dijitalleşme, Hizmet ticareti, Küresel değer zincirlerine entegrasyon	Mal, Hizmet, Yatırım, Fikri mülkiyet, Dijital ticaret, Sürdürülebilirlik	Kapsamlı ve derinleşen anlaşmalar, Coğrafi çeşitlendirme, Yeni nesil ticaret konuları

Kaynak: Akman (2010), Yaman (2016) ve T.C. Ticaret Bakanlığı verilerinden yararlanılarak hazırlanmıştır.

Türkiye'nin uluslararası arenada attığı ilk somut STA adımı, Tablo 1'de belirtilen ilk dönemin ruhuna uygun olarak, Avrupa Birliği'nin tercihli ticaret rejimini üstlenmeye yönelik kurumsal bir hazırlık mahiyetinde Avrupa Serbest Ticaret Birliği (EFTA) ile atılmıştır. 10 Aralık 1991'de imzalanıp 1 Nisan 1992'de yürürlüğe giren EFTA Anlaşması ile taraflar arasındaki tüm sanayi mallarında uygulanan tarife ve eş etkili miktar kısıtlamaları lağvedilerek serbest dolaşım tesis edilmiştir. Doğan ve Uzun (2014) analizlerinde, Türkiye'nin bu ilk deneyimindeki asıl motivasyonunun ihracatta ürün çeşitliliğini yakalamak ve nitelikli pazarlara doğrudan erişim sağlamak olduğunu vurgulamaktadır.

Türkiye'nin STA'larında asıl büyük kırılma ise Avrupa Birliği (AB) ile olan kurumsal entegrasyon sürecinde yaşanmıştır. 1959'da başlayan üyelik serüveni ivme kazanarak, 6 Mart 1995 tarihli ve 1/95 sayılı Ortaklık Konseyi Kararı ile Gümrük Birliği'nin kurulmasıyla

sonuçlanmıştır. 1 Ocak 1996'da yürürlüğe giren bu bütünleşme çerçevesinde, sanayi ürünlerindeki karşılıklı gümrük tarifeleri ve kotalar sıfırlanmış; işlenmiş tarım ürünlerindeki sanayi payı da gümrük vergisinden muaf tutulmuştur. Bu tarihi adımın dış ticaret politikasına yansımaları son derece bağlayıcı olmuştur. Kararın 16. maddesi uyarınca Türkiye, üçüncü ülkelere karşı AB'nin Ortak Gümrük Tarifesi'ni uygulamakla ve AB'nin tercihli ticaret rejimini beş yıl içerisinde üstlenmekle yükümlü kılınmıştır. Erdem (2015)'in de belirttiği üzere, bu katı yükümlülüğün doğal bir sonucu olarak Türkiye; AB'nin geliştirdiği tercihli sistemleri benimsemiş, özellikle Orta ve Doğu Avrupa, Kuzey Afrika ve Akdeniz havzasındaki çok sayıda ülkeyle ardı ardına STA'lar imzalamak zorunda kalmıştır. Bu anlaşmalar, Türk ihracatçılarının özellikle AB'li rakipleriyle üçüncü pazarlarda eşit şartlarda rekabet edebilmesinin bir garantisi olarak görülmüştür. Ne var ki Kalaycı (2017), bu hukuki uyum zorunluluğunun Türkiye'yi AB'nin metinlerini noktası virgülüne kadar kabul etmeye mecbur bırakmadığını; Türkiye'nin müzakere süreçlerinde kendi sanayi politikası önceliklerini ve yerel hassasiyetlerini titizlikle masaya koyabildiğini belirtmektedir.

Ticaret Bakanlığı'nın (2026) güncel verilerine göre, Türkiye'nin bugüne kadar akdettiği toplam 38 adet Serbest Ticaret Anlaşması'nın (STA) 12'si çeşitli dinamikler neticesinde feshedilmiştir; bunların 11'i ilgili Merkezi ve Doğu Avrupa ülkelerinin Avrupa Birliği'ne tam üye olmaları hasebiyle Gümrük Birliği mevzuatına devredilmiş, biri ise ikili çerçevede yürürlükten kalkmıştır. Suriye ve İsrail ile olan anlaşmaların mevcut konjonktürde askıya alınması ve çeşitli ülkelerle devam eden iç onay süreçlerine rağmen; EFTA'dan Güney Kore'ye, Şili'den Malezya'ya kadar uzanan geniş bir coğrafyada geriye kalan 24 adet kapsamlı STA hali hazırda aktif olarak uygulanmaktadır. Bu anlaşmalar, Türkiye'nin küresel rekabet gücünü tahkim eden önemli enstrümanlar olarak işlev görmeye devam etmektedir. Ticaret Bakanlığı raporlarında da altı çizildiği üzere bu geniş ve dinamik anlaşma ağı, ülkenin salt ticaretini kolaylaştırmakla kalmamakta, makroekonomik altyapısının küresel değer zincirlerine kalıcı ve derin bir entegrasyonunu güvence altına almaktadır.

Türkiye'nin EFTA ile başlayan ve Gümrük Birliği'nin yasal zorunluluklarını aşarak proaktif bir ticaret diplomasisine dönüşen bu çok boyutlu entegrasyon süreci, son yıllarda eksenini küresel ekonomik büyümenin yeni ağırlık merkezi olan Asya-Pasifik bölgesine doğru kaydırmıştır. Bu stratejik pazar çeşitlendirmesi politikasının en somut ve kritik çıktılarında biri ise, Güneydoğu Asya Uluslar Birliği (ASEAN) bölgesinin kilit aktörlerinden Malezya ile kurulan kurumsal ticari köprüdür. Bu bağlamda, çalışmanın takip eden bölümünde; genel hatları çizilen bu ulusal STA vizyonunun spesifik bir yansıması olarak Türkiye ve Malezya arasındaki ekonomik

ilişkilerin arka planı, imzalanan anlaşmanın yasal kapsamı ve bu entegrasyonun ikili ticaret mimarisinde yarattığı yapısal dönüşümler analize tabi tutulacaktır.

3. Türkiye ve Malezya Arasındaki Serbest Ticaret İlişisine Genel Bir Bakış

Türkiye'nin Asya-Pasifik açılımının en önemli stratejik ayaklarından birini oluşturan Malezya ile ikili ilişkileri, derin tarihsel ve diplomatik temellere dayanmaktadır. Türkiye'nin Kuala Lumpur'da, Malezya'nın ise Ankara'da büyükelçilikleri bulunmakta olup, ayrıca Malezya'nın İstanbul'da bir konsoloslugu faaliyet göstermektedir. Her iki ülke de kendi coğrafyalarında stratejik orta güç kategorisinde sınıflandırılmakta olup, Dünya Ticaret Örgütü ve İslam İşbirliği Teşkilatı gibi küresel mecralarda tam üye statüsüyle ortak hareket etmektedirler. Malezya'nın ASEAN içindeki kilit konumu ve Singapur, Endonezya, Tayland, Vietnam gibi hızla büyüyen pazarlara komşuluğu, bu ülkeyi bölgesel ticarete vazgeçilmez bir lojistik ve üretim merkezi yapmaktadır. Bu stratejik avantajlar doğrultusunda Malezya, Türkiye Cumhuriyeti Ticaret Bakanlığı tarafından 2024-2025 dönemi için öncelikli ülkeler listesine alınarak ikili ticari potansiyeli tescillenmiş bir pazar konumundadır.

Bu güçlü altyapı üzerinde inşa edilen Türkiye-Malezya Serbest Ticaret Anlaşması (TM-STA), ikili ekonomik ilişkileri dönüştürme hedefiyle 1 Ağustos 2015 tarihinde yürürlüğe girmiştir. Bu anlaşma ile Türkiye; Asya-Pasifik bölgesinde Güney Kore'den sonra ikinci, Güneydoğu Asya bölgesinde ise ilk STA'sını Malezya ile akdetmiş ve Avrupa Birliği'nden daha önce bu pazara tercihli erişim hakkı kazanarak ihracatçılarına önemli bir ilk hareket avantajı sağlamıştır.

STA'nın uygulamaya alınmasıyla birlikte, tarife cetvellerinin yaklaşık %70'inde gümrük vergileri anında karşılıklı olarak sıfırlanmıştır. Yürürlüğe giriş anı itibarıyla Malezya'ya yapılan ihracatın %71'i ve ithalatın %69'u gümrükten muaf tutulmuştur. Kalan kalemler için ise 3, 5 ve 8 yıllık takvimlere yayılan kademeli geçiş dönemleri benimsenmiştir. Sekiz yıllık bu geçiş süreci tamamlandığında; tarife satır sayısı bazında Türkiye'nin ihracatının %99'u, ithalatının ise %86'sı gümrük vergisinden muaf hale gelecek şekilde kurgulanmıştır.

Sektörel bazda incelendiğinde asimetrik ve hassas ürün yapıları göze çarpmaktadır. Sanayi ürünlerinde, Malezya'nın uyguladığı gümrük vergilerinin 2018 yılı itibarıyla %80'i kaldırılmış olup, en geç sekiz yılın sonunda tamamen sıfırlanması taahhüt edilmiştir. Tarım ürünleri alanında ise; nar, kavun, karpuz ve kakaolu sürdürülebilir ürünler dışında kalan tüm tarım ürünlerinde 2018 itibarıyla gümrük vergileri sıfırlanırken; dondurulmuş kanatlı eti ve yumurta gibi hassas ürünlerde tarife kotası bazında muafiyetler sağlanmış, bazı margarin ürünlerinde ise %20'lik vergi indirimine gidilmiştir. Bununla birlikte Türkiye'nin toplam ithalatında ciddi bir ağırlığı olan palm yağı ve türevlerindeki gümrük vergileri %31,2'den %21,8'e

düşürülmüştür. Alkol, tütün mamulleri ve pirinç gibi ürünler ise Malezya'nın genel STA politikaları çerçevesinde anlaşma kapsamı dışında bırakılmıştır.

İkili ticari mimariyi çağdaşlaştırma ve derinleştirme vizyonu çerçevesinde, başlangıçta salt mal ticareti odaklı olan anlaşmanın kapsamı, Mart 2018'de başlatılan müzakereler sonucunda genişletilmiştir. Hizmet Ticareti ve Yatırım başlıklarını STA'ya entegre eden 1 No'lu Revize Protokol, 22 Eylül 2022'de başarıyla tamamlanmış, 29 Eylül 2022 tarihinde imzalanmış ve iç hukuk onay süreçlerinin ardından 1 Ağustos 2024 tarihinde resmi olarak yürürlüğe girmiştir. Bu yapısal genişleme, Malezya'yı Türkiye için sadece bir mal ihrac pazarı olmaktan çıkararak, müteahhitlikten lojistiğe uzanan geniş bir yelpazede hizmet ihracatı ve karşılıklı doğrudan yabancı yatırım merkezine dönüştürme potansiyeli taşımaktadır.

Malezya'nın küresel pazarlara entegrasyon kapasitesini ve Türkiye'nin bu pazar üzerinden elde edebileceği üçüncü ülke erişim potansiyelini anlamak adına, Malezya'nın yürürlükte olan ve uluslararası hukuka uygun biçimde akdettiği ikili ve bölgesel ticaret anlaşmaları Tablo 2'de sunulmuştur.

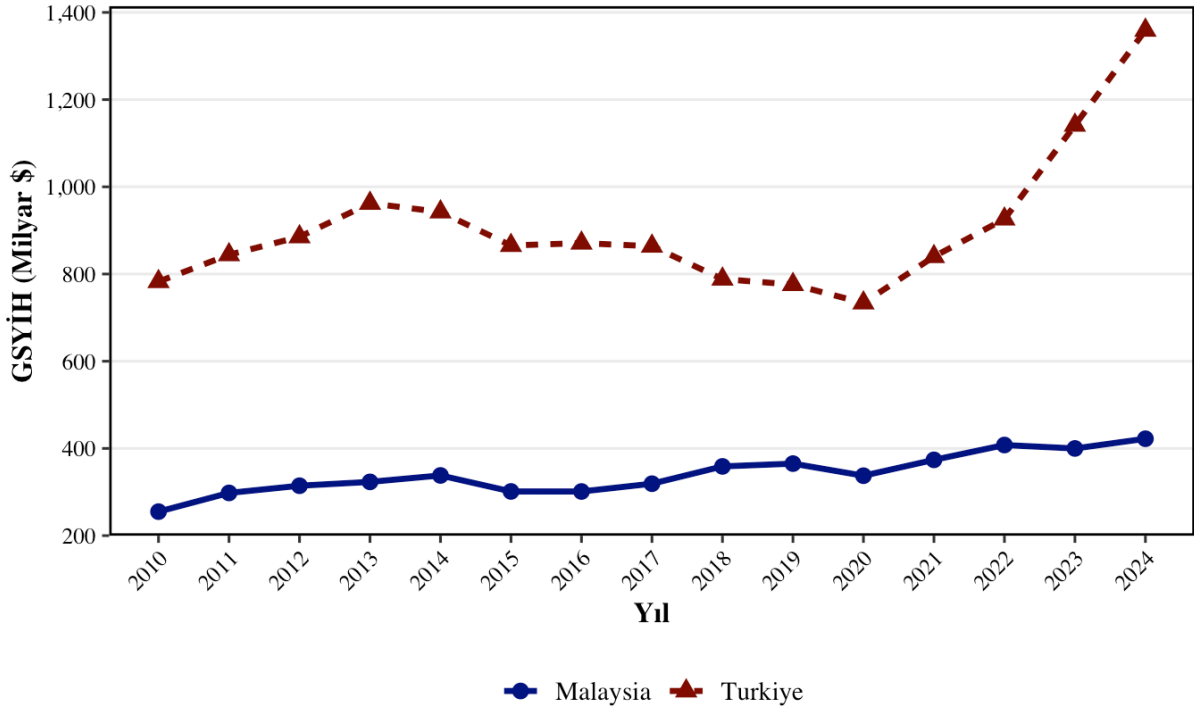
Tablo 1 Malezya'nın İkili ve Bölgesel Ticaret Anlaşmaları

#	Anlaşma (Kısaltma)	Tür	İmzalanma Tarihi	Yürürlük Tarihi
1	Malezya-Japonya Economic Partnership (MJEP)	İkili	13 Aralık 2005	13 Temmuz 2006
2	Malezya-Pakistan Closer Economic Partnership (MPCEPA)	İkili	8 Kasım 2007	1 Ocak 2008
3	Malezya-Yeni Zelanda FTA (MNZFTA)	İkili	26 Ekim 2009	1 Ağustos 2010
4	Malezya-Hindistan Comprehensive Economic Cooperation (MICECA)	İkili	18 Şubat 2011	1 Temmuz 2011
5	Malezya-Şili Free Trade Agreement (MCFTA)	İkili	13 Kasım 2010	25 Şubat 2012
6	Malezya-Avustralya Free Trade Agreement (MAFTA)	İkili	30 Mart 2012	1 Ocak 2013
7	Malezya-Türkiye Free Trade Agreement (MTFTA)	İkili	17 Nisan 2014	1 Ağustos 2015
8	ASEAN-Çin FTA (ACFTA)	Bölgesel	Kasım 2002	1 Ocak 2010
9	ASEAN-Japonya CEP (AJCEP)	Bölgesel	14 Nisan 2008	1 Şubat 2009
10	ASEAN-Kore FTA (AKFTA)	Bölgesel	-	1 Ocak 2010
11	ASEAN-Hindistan FTA (AIFTA)	Bölgesel	13 Ağustos 2009	1 Ocak 2010
12	ASEAN-Avustralya-Yeni Zelanda FTA (AANZFTA)	Bölgesel	27 Şubat 2009	1 Ocak 2010
13	ASEAN-Hong Kong, Çin FTA (AHKFTA)	Bölgesel	12 Kasım 2017	13 Ekim 2019
14	Bölgesel Kapsamlı Ekonomik Ortaklık (RCEP)	Bölgesel	15 Kasım 2020	18 Mart 2022
15	Kapsamlı ve Aşamalı Trans-Pasifik Ortaklığı Anlaşması (CPTPP)	Bölgesel	8 Mart 2018	29 Kasım 2022
16	ASEAN Serbest Ticaret Bölgesi (AFTA/ATIGA)	Bölgesel	1993	1993

Kaynak: MITI. (2025). *Malaysia's Free Trade Agreements*. Ministry of Investment, Trade and Industry Malaysia. Erişim adresi: <https://www.miti.gov.my/index.php/pages/view/fta>

4. Türkiye ve Malezya Ekonomilerinin Karşılaştırılması ve Ticarete Konu Olan Başlıca Ürünler

Malezya 2024 yılı itibariyle GSYİH'ye göre yaklaşık 421 milyar ABD doları ile dünyanın en büyük 38. ekonomisi içinde yer alırken Türkiye ise 1,3 trilyon ABD doları ile 18. sırada yer almaktadır. Her iki ülkenin 2010-2024 yıllarına ait GSYİH verileri şekil 1'de gösterilmiştir.



Şekil 1 Türkiye ve Malezya GSYİH karşılaştırılması (Cari fiyatlarla milyar ABD doları)
Kaynak: Dünya Bankası, 2025

Şekil 1, Türkiye ve Malezya'nın 2010-2024 yılları arasındaki gayrisafi yurt içi hasıla gelişimini cari fiyatlarla milyar ABD doları bazında karşılaştırmalı olarak sunmaktadır. İncelenen dönem boyunca Türkiye ekonomisinin, makroekonomik büyüklük açısından Malezya'ya kıyasla mutlak bir hacim üstünlüğüne sahip olduğu açıkça görülmektedir. Malezya ekonomisi, 2010 yılında yaklaşık 250 milyar dolar seviyesinden başlayarak 14 yıllık periyotta küresel şoklardan nispeten az etkilenen, istikrarlı ve ılımlı bir büyüme trendi izlemiştir; 2024 yılı itibarıyla 400 milyar dolar seviyesinin hemen üzerine tırmanarak yapısal bir stabilite sergilemiştir. Buna karşın Türkiye ekonomisi belirgin bir makroekonomik volatilité ortaya koymuştur. Türkiye ekonomisi, 2013 yılında 1 trilyon dolar sınırına yaklaşarak ilk nominal zirvesini yapmış, ardından 2020 yılına kadar devam eden kademeli bir daralma eğilimiyle 750 milyar dolar bandına kadar gerilemiştir. Ancak 2020 yılından itibaren son derece keskin ve agresif bir nominal genişleme ivmesi yakalayan Türkiye GSYİH'si, dramatik bir artışla 2024 yılında

yaklaşık 1,4 trilyon dolar seviyesine ulaşarak incelenen dönemin en yüksek makroekonomik büyüklüğünü kaydetmiştir. Bu kapsamda, STA'nın yürürlükte olduğu 2015 ve sonrası dönemde iki ülkenin büyüme dinamiklerinde ve nominal gelir yaratma kapasitelerinde derin farklılıklar bulunduğunu açıkça anlaşılmaktadır.

Tablo 2: Türkiye Dış Ticaret İstatistikleri (milyar ABD doları) (2013-2025)

Yıl	İhracat	İthalat	Ticaret Dengesi	Dış Ticaret Hacmi
2013	161,48	260,82	-99,34	422,30
2014	166,50	251,14	-84,64	417,65
2015	150,98	213,62	-62,64	364,60
2016	149,25	202,19	-52,94	351,44
2017	164,49	238,72	-74,22	403,21
2018	177,17	231,15	-53,98	408,32
2019	180,83	210,35	-29,51	391,18
2020	169,64	219,52	-49,88	389,15
2021	225,21	271,43	-46,21	496,64
2022	254,17	363,71	-109,54	617,88
2023	255,63	361,97	-106,34	617,59
2024	261,78	344,01	-82,23	605,79
2025	273,31	365,43	-92,12	638,74

Kaynak: Türkiye İstatistik Kurumu (t.y.)

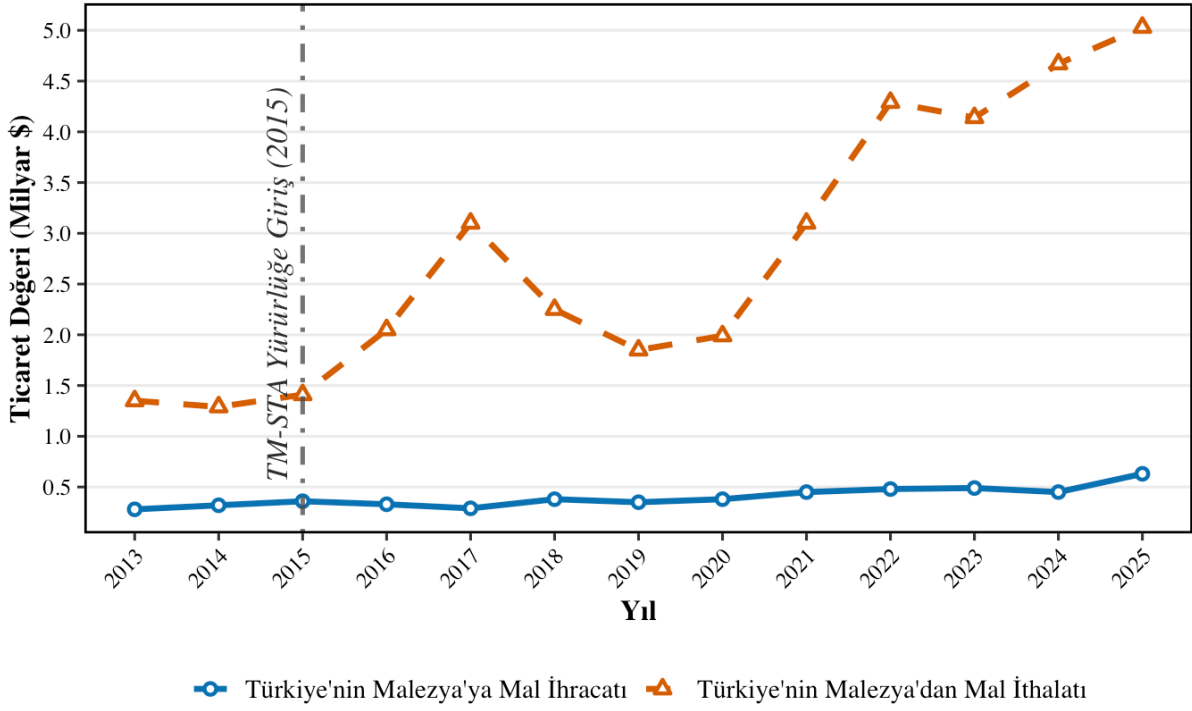
Tablo 3, Türkiye'nin 2013-2025 yılları arasındaki genel dış ticaret performansını milyar ABD doları cinsinden özetlemektedir. İncelenen dönem itibarıyla Türkiye'nin dış ticaret hacmi 2013-2016 yılları arasında küresel ve yerel konjonktürün de etkisiyle 422,30 milyardan 351,44 milyar dolara doğru belirgin bir daralma yaşanmıştır. Bu süreçte ticaret açığı nispeten daralmış ve 2019 yılında -29,51 milyar dolar ile dönemin en düşük seviyesine gerilemiştir. Ancak 2021 yılından itibaren Türkiye'nin dış ticaret hacminde agresif bir nominal genişleme evresine girildiği; 2025 yılı itibarıyla ihracatın 273,31 milyar dolara, dış ticaret hacminin ise tarihi bir seviye olan 638,74 milyar dolara ulaştığı görülmektedir. Buna karşın, 2022 yılında ithalatın 363,71 milyar dolara yükselmesiyle dış ticaret açığı -109,54 milyar dolar gibi dramatik bir zirveye ulaşmış ve 2025 yılına gelindiğinde ihracattaki rekor artışlara rağmen -92,12 milyar dolarlık yüksek açık kronik karakterini korumuştur. Bu veriler, Türkiye'nin dış pazarlara entegrasyonu ve ticaret kapasitesi artarken, aynı zamanda ithalata dayalı üretim modelinin yarattığı makroekonomik asimetriyi ve ticaret açığı sarmalını ampirik olarak teyit etmektedir. Türkiye'nin 2013-2025 dönemini kapsayan dış ticaret projeksiyonu ve makroekonomik asimetrisi bu şekilde tezahür ederken; iki ülke arasındaki ticari rejimleri düzenleyen STA'nın diğer tarafını teşkil eden Malezya'nın dış ticaret dinamikleri ve dönemsel istatistikleri, karşılaştırmalı bir perspektif sunmak amacıyla Tablo 4'te sunulmuştur.

Tablo 3 Malezya Dış Ticaret İstatistikleri (milyar ABD doları) (2013-2024)

Yıl	İhracat	İthalat	Ticaret Dengesi	Dış Ticaret Hacmi
2013	228,33	205,897	22,43	434,23
2014	233,93	208,851	25,08	442,78
2015	199,95	175,971	23,98	375,92
2016	189,74	168,684	21,06	358,43
2017	218,13	195,417	22,71	413,55
2018	247,46	217,602	29,85	465,06
2019	238,20	204,998	33,20	443,19
2020	234,77	190,86	43,91	425,63
2021	299,43	238,24	61,19	537,67
2022	352,09	293,797	58,30	645,89
2023	312,97	265,667	47,30	578,63
2024	330,42	300,355	30,06	630,77

Kaynak: World Bank. (t.y.).

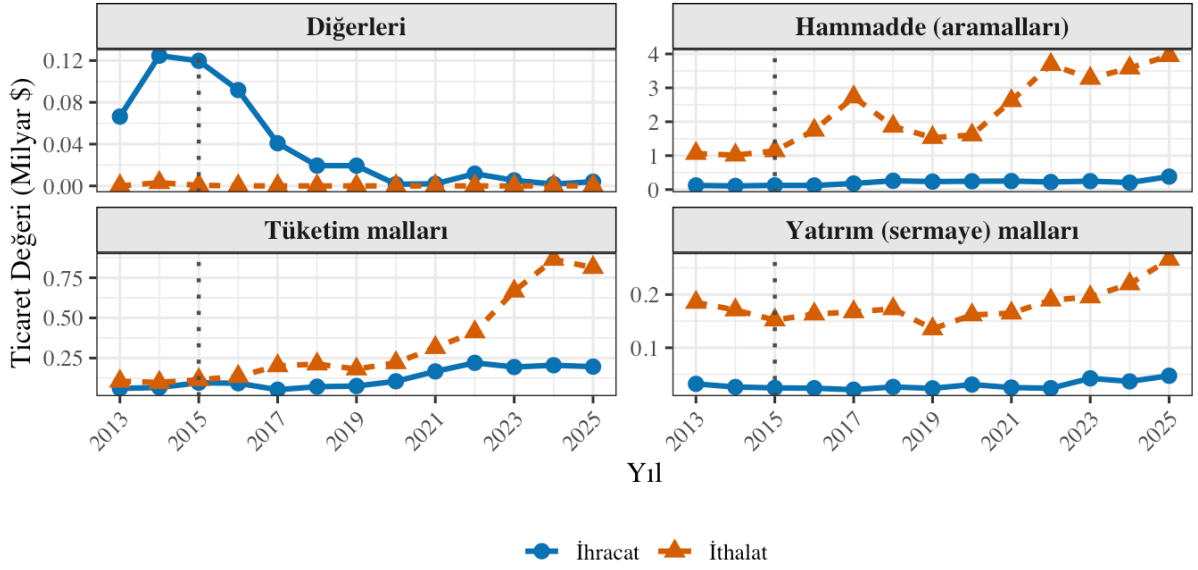
Tablo 4, Malezya'nın ihracata dayalı ve son derece rekabetçi makroekonomik yapısını 2013-2024 dönemi dış ticaret istatistikleri üzerinden net bir biçimde gözler önüne sermektedir. İncelenen 12 yıllık periyot boyunca Malezya, istisnasız her yıl düzenli olarak dış ticaret fazlası vererek yapısal bir istikrar sergilemiş; özellikle 2021 ve 2022 yıllarında bu ticaret fazlası sırasıyla 61,19 milyar dolar ve 58,30 milyar dolar seviyelerine ulaşarak dönemin zirvesini görmüştür. 2016 yılında 358,43 milyar dolar olan toplam dış ticaret hacmi ise güçlü bir genişleme ivmesiyle 2024 yılı itibarıyla 630,77 milyar dolara ulaşmıştır. Bu tablodaki verileri iktisadi açıdan çarpıcı kılan asıl unsur ise Malezya'nın makroekonomik ölçeği ile dış ticaret performansı arasındaki devasa orantısızlıktır. Nitekim Şekil 1'de belirtildiği üzere Malezya'nın Gayrisafi Yurt İçi Hasılası (421 milyar dolar), Türkiye'nin GSYİH'sinin (yaklaşık 1,4 trilyon dolar) üçte birinden daha küçük olmasına rağmen, Malezya'nın ürettiği dış ticaret hacmi Türkiye'nin dış ticaret hacminden 2023 yılı hariç tüm yıllarda daha yüksek bir seviyede gerçekleşmiştir. GSYİH'sini aşan bu devasa ticaret hacmi, Malezya ekonomisinin iç tüketime değil, doğrudan küresel değer zincirlerine entegre olmuş yüksek katma değerli bir ihracat modeline dayandığını göstermektedir.



Şekil 2 Türkiye ve Malezya İkili Ticaret Hacmi Gelişimi (2013-2025)

Kaynak: Türkiye İstatistik Kurumu. (t.y).

Şekil 2’de, Türkiye ile Malezya arasındaki dış ticaret değerleri ithalat ve ihracat bazından yıllar itibarıyla sunulmuştur. Bu grafik 2015 yılındaki TM-STA yürürlüğe girişi ile serbestleşmenin taraflar üzerindeki asimetrik etkisi net bir şekilde görselleştirmektedir. Anlaşma öncesi 2013-2015 döneminde nispeten dar bir makasta seyreden ikili ticaret hacmi, anlaşmanın devreye girmesi ile birlikte Türkiye'nin ithalatı lehine şiddetli bir ivmelenme göstermiştir. Yatay ekseninde durağan bir trend izleyen ihracata karşılık, ithalatın 2015 sonrasında yukarı yönlü bir seyir izlemesi, pazar entegrasyonundan orantısız biçimde Malezya'nın yararlandığını ve dış ticaret açığındaki genişlemenin kronik bir hâl aldığını açıkça göstermektedir.

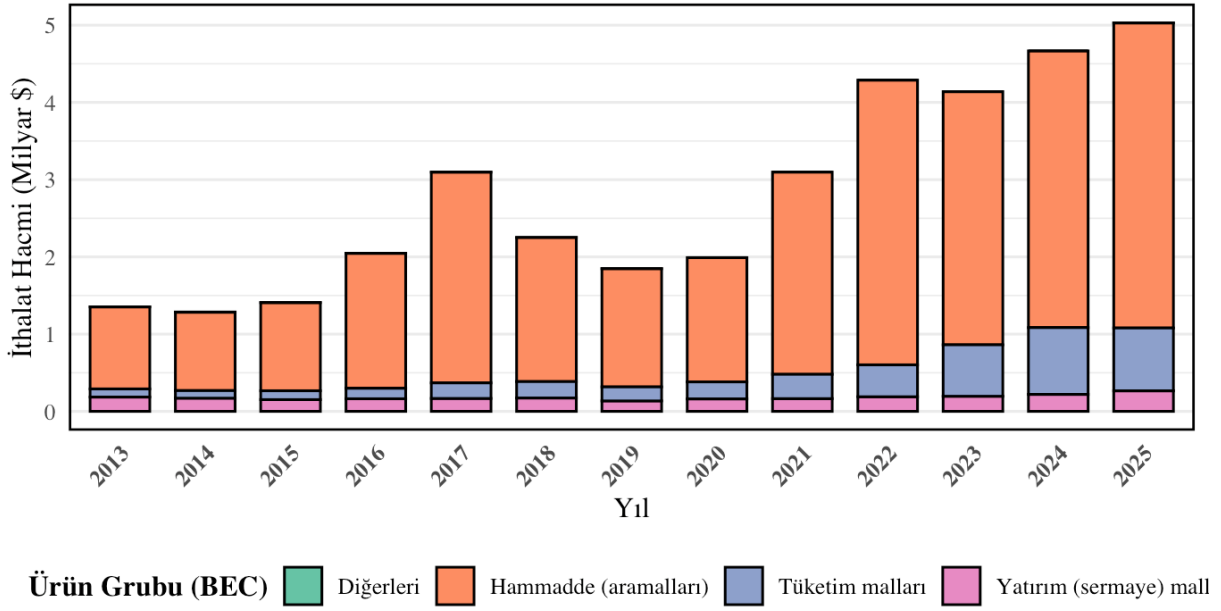


Şekil 3 Geniş Ekonomik Kategorilere (BEC) Göre Türkiye-Malezya Ticareti

Kaynak: Türkiye İstatistik Kurumu, (t.y.)

Açıklama: Milyar ABD doları (2013-2025) | Noktalı Çizgi: 2015 STA Başlangıcı

Şekil 3, Türkiye ile Malezyya arasındaki ikili ticaret hacmini geniş ekonomik kategoriler (BEC) bazında ayırarak, makro ölçekteki dış ticaret açığının ardındaki yapısal dinamikleri ortaya koymaktadır. Panel grafik incelendiğinde, tüketim ve yatırım malları kategorilerinde iki ülke arasındaki ticaretin nispeten düşük hacimli ve yatay bir seyir izlediği görülürken, asıl farklılığın hammadde (aramaları) grubunda yaşandığı net biçimde görünmektedir. 2015 yılında STA'nın yürürlüğe girmesini temsil eden dikey kırılma çizgisinden sonra, Türkiye'nin Malezyya'ya yönelik hammadde ihracatı durağan bir seyir izlerken, Malezya'dan yapılan hammadde ithalatı agresif bir artış trendine girmiş ve 4 milyar dolar seviyelerine kadar yükselmiştir. Bu bulgu, Türkiye'nin Malezyya'ya karşı verdiği kronik ticaret açığının genel bir rekabet zafiyetinden ziyade, Türk imalat sanayisinin Malezyya menşeli temel endüstriyel girdilere yönelik derin ve yapısal bir ara malı bağımlılığından kaynaklandığını göstermektedir.



Şekil 4 Türkiye'nin Malezya'dan İthalatının Sektörel Kompozisyonu

Kaynak: Türkiye İstatistik Kurumu, (t.y.)

Şekil 4, Türkiye'nin Malezya'dan gerçekleştirdiği ithalatın içsel yapısına odaklanarak, ticaret hacmindeki büyümenin sektörel niteliğini detaylandırmaktadır. Yığılmış çubuk grafiği, yıllar itibarıyla artan toplam ithalat içerisinde hammadde kategorisinin oransal üstünlüğünü net bir şekilde ortaya koymaktadır. İthalatın geri kalan kısmını oluşturan tüketim ve yatırım mallarının payı ise ilgili yıllar itibarıyla son derece sınırlı kalmıştır.

T.C. Ticaret Bakanlığı (2025) tarafından yayımlanan veriler ışığında, Malezya'nın dış ticaret projeksiyonu incelendiğinde, 2024 yılı verilerine göre Türkiye'nin Malezya'ya yaptığı ihracatta en belirgin kalem, toplam ihracatın %25,3'ünü oluşturan kıymetli veya yarı kıymetli taşlar olmuştur. Bu fasılda ihracat bir önceki yıla göre %49,8 artarak 113,6 milyon dolara ulaşmıştır. İhracatta bir diğer öne çıkan kalemler arasında inorganik kimyasallar (%9), makine ve mekanik cihazlar (%8,1) ve yenilen meyveler (%6,8) yer almakta olup, özellikle meyve ihracatı %125,9'luk dikkat çekici bir artışla 30,7 milyon dolara ulaşmıştır. İlk 10 fasıl, Malezya'ya yapılan toplam ihracatın %87,2'sini oluşturarak ihracatın dar bir ürün yelpazesine yoğunlaştığını ortaya koymaktadır.

İthalat tarafında ise yapısal bağımlılığın boyutları çok daha belirgin biçimde kendini göstermektedir. 2024 yılında Malezya'dan yapılan ithalatın en büyük kalemi, bir önceki yıla göre %164,5 gibi dramatik bir artışla 1,23 milyar dolara ulaşan demir ve çelik olmuştur. Bu fasılın toplam ithalattaki payı %11,3'ten %26,4'e yükselmiştir. İkinci sırada %17,2 payla hayvansal ve bitkisel katı-sıvı yağlar (özellikle palm yağı ve fraksiyonları 660 milyon dolar) yer alırken, bunu %14,8 payla elektrikli makine ve cihazlar ve %7,6 payla işlenmemiş

alüminyum takip etmektedir. İlk 5 fasıl ithalatın %70'ini, ilk 10 fasıl ise %94'ünü oluşturmakta olup bu durum, Türkiye'nin Malezya'dan yaptığı ithalatın ağırlıklı olarak endüstriyel girdi niteliğindeki aramallarından oluştuğunu teyit etmektedir (T.C. Ticaret Bakanlığı, 2025).

Malezya perspektifinden değerlendirildiğinde, Türkiye'nin bu ülkenin toplam ihracatındaki payı 2024'te %1,4 düzeyinde gerçekleşmiş ve Malezya'nın en çok ihracat yaptığı 15. ülke konumuna yükselmiştir. Türkiye özellikle palm yağı ve fraksiyonlarında Malezya'nın toplam ihracatının %3,9'unu, işlenmemiş alüminyumda %6,1'ini ve vulkanize kauçuk eldivenlerde %3'ünü absorbe ederek bu kalemlerde önemli bir pazar olma özelliğini sürdürmüştür. Öte yandan Malezya'nın toplam ihracatında %23,3 ile elektronik entegre devreler, %12,3 ile petrol ürünleri ve %9,7 ile makine-cihazlar baskın konumunu korurken, Türkiye bu yüksek katma değerli ürün gruplarında Malezya'nın ihracatından son derece düşük bir pay almaktadır.

İkili ticaret verileri, Türkiye'nin Malezya ile olan ilişkisini doğrudan tüketim odaklı bir dış ticaret bağımlılığından ziyade, üretim süreçlerine bütünleşmiş bir girdi tedariki modeli üzerine kurguladığını göstermektedir. Bu bağlamda, dış ticaret açığındaki genişleme, Türk sanayisinin Malezya menşeli kritik ara mallarına yönelik türetilmiş talebi ile doğrudan ilişkilidir. Ancak, bu durumun bir fırsat mı yoksa kırılganlık mı olduğu, ithal edilen bu girdilerin Türkiye içindeki katma değer yaratma potansiyeline ve üçüncü ülkelere yönelik ihracata ne ölçüde tahvil edilebildiğine bağlıdır. Netice itibarıyla, Türkiye'nin Malezya ile ticareti, tüketim kanalıyla refah sızıntısı yaratan bir yapıdan ziyade, sanayinin üretim dışlilerini besleyen stratejik bir hammadde kanalı niteliği taşımaktadır.

5. Sonuç

Türkiye-Malezya Serbest Ticaret Anlaşması, 1 Ağustos 2015 tarihinde yürürlüğe girdiğinden bu yana iki ülke arasındaki ekonomik ilişkileri dönüştürme potansiyeli yüksek, ancak yapısal asimetri belirlendiği karmaşık bir entegrasyon süreci ortaya koymuştur. TM-STA, yürürlüğe girişiyle birlikte tarife cetvellerinin yaklaşık yüzde yetmişinde gümrük vergilerini anında sıfırlamış; sekiz yıllık geçiş takviminin sonunda Türkiye'nin ihracatının yüzde doksan dokuzunu, ithalatının ise yüzde seksen altısını gümrükten muaf hale getirmeyi hedefleyen kapsamlı bir liberalleşme çerçevesi sunmuştur. Bu çerçevede iki ülke arasındaki ikili ticaret hacmi önceki dönemlere kıyasla kayda değer bir genişleme kaydetmiş; kimyevi maddeler, makine ile elektrik-elektronik sektörlerinde belirli ihracat kazanımları elde edilmiştir. Öte yandan mal ticaretinin ötesine geçilerek hizmetler ve yatırımları da kapsama dahil eden 1 No'lu Revize Protokol'ün 1 Ağustos 2024 tarihinde yürürlüğe girmesi, ikili ekonomik bütünleşme için daha derin ve kurumsal bir zemin oluşturmuştur.

Bununla birlikte, ampirik veriler anlaşmanın Türkiye açısından belirgin biçimde asimetrik sonuçlar doğurduğuna işaret etmektedir. Şekil 2 ve Şekil 3'te de açıkça görüldüğü üzere, STA'nın yürürlüğe girmesinin ardından Türkiye'nin Malezya'ya yönelik ihracatı durağan bir seyir izlerken, Malezya'dan yapılan ithalat hızlı ve sürekli bir artış trendine girmiştir. Bu tablonun temelinde, Şekil 3 ve Şekil 4'ün ortaya koyduğu üzere, Türk imalat sanayisinin Malezya menşeli temel endüstriyel girdilere olan yapısal bağımlılığı yatmaktadır. Söz konusu aramalı ithalat ağırlığı, ikili ticaret dengesinin aleyhte seyretmesinin ardındaki başlıca yapısal etken olarak öne çıkmakta ve bu durumun genel bir rekabet zafiyetinden ziyade sektöre özgü bir bağımlılık ilişkisinden kaynaklandığını göstermektedir.

Mevzuat boyutundaki gelişmelere bakıldığında, anlaşmanın etkin uygulanmasına yönelik düzenlemelerin sürdüğü görülmektedir. 27 Aralık 2024 tarihli ve 32765 sayılı Resmî Gazete'de yayımlanan değişiklik; pandemi dönemindeki ticaret aksaklıklarını gidermek amacıyla 1 Nisan 2020 ile 1 Nisan 2023 tarihleri arasındaki ihracat işlemleri için 31 Ekim 2024'ten itibaren bir yıl süreyle sonradan menşe belgesi düzenlenmesine olanak tanıyan geçici bir hüküm eklenmiştir. Buna ek olarak, 8 Ekim 2025 tarihli ve 33041 sayılı Resmî Gazete'de yayımlanan yönetmelik değişikliğiyle menşe kurallarının uygulanmasına ilişkin teknik düzenlemeler de hayata geçirilmiştir. Bu gelişmeler, anlaşmanın işlerliğinin korunmasına ve ticari sürtünmelerin azaltılmasına katkı sunmaktadır.

Sonuç olarak, TM-STA'nın Türkiye açısından sürdürülebilir ve dengeli bir zemine oturtulması, çok boyutlu bir strateji gerektirmektedir. Kısa vadede, 1 Ağustos 2024'te yürürlüğe giren Hizmetler ve Yatırımlar Protokolü'nün müteahhitlik, lojistik ve mühendislik gibi Türkiye'nin rekabetçi olduğu alanlarda etkin biçimde kullanılması öncelikli hedef olmalıdır. Orta vadede ise hedefli sektörel destekler, sistematik pazar araştırması ve yüksek katma değerli ürün ihracatına odaklanmayı içeren somut eylem planlarının hayata geçirilmesi gerekmektedir. Türkiye ile Malezya arasındaki köklü tarihsel bağlar ve örtüşen stratejik çıkarlar, bu ortaklığın daha dengeli bir yapıya kavuşturulması için elverişli bir zemin sunmaktadır. Ancak bu potansiyelin gerçeğe dönüştürülmesi, güçlü bir siyasi irade, koordineli bir kamu-özel sektör iş birliği ve proaktif bir ticaret diplomasisini zorunlu kılmaktadır.

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DİJİTAL KÜLTÜRDE ÖTEKİNİN SİLİNMESİ: AYNILIĞIN ÇOĞALMASI VE NEGATİFLİĞİN KAYBI

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ÖZET

Geç modern toplum, dijitalleşmenin etkisiyle sınırsız iletişim ve çoğulculuk iddiası taşımaktadır. Sosyal medya platformları ve algoritmik içerik akışları, farklı görüş ve kimliklerin görünür olduğu bir kamusal alan izlenimi yaratmaktadır. Ancak bu görünür çoğulluk, farklı olanla gerçek karşılaşma imkânını her zaman güçlendirmemektedir. Byung-Chul Han, Ötekini Kovmak adlı eserinde çağdaş toplumun temel krizlerinden birinin “ötekinin kaybı” olduğunu ileri sürmektedir. Han’a göre modern kültür, farklı olanı açık bir çatışma yoluyla dışlamaktan ziyade benzerlik üretimi yoluyla etkisizleştirmekte ve nötralize etmektedir. Böylece öteki, doğrudan kovulmaktan çok görünmez biçimde silinmektedir. Bu çalışma, Han’ın “negatifliğin kaybı”, “aynının çoğalması” ve “narsisistik kapanma” kavramlarını dijital kültür bağlamında sosyolojik bir perspektifle ele almaktadır. Özellikle algoritmik kişiselleştirme mekanizmaları, içerik öneri sistemleri ve yankı odaları, bireylerin benzer görüş ve içeriklerle karşılaşma olasılığını artırmakta; farklı olanla karşılaşma deneyimini sınırlandırmaktadır. Dijital ortamda “takip et” ve “engelle” pratikleri de konfor bozucu içeriklerin hızla dışlanmasına imkân tanımaktadır. Bu süreç, açık bir baskıdan ziyade homojenleştirici bir kültürel yapı üretmektedir. Çalışma, dijital kültürdeki benzerlik eğiliminin yalnızca teknik bir algoritma sonucu değil; öznenin konfor arayışı ve kendine yönelimli kapanışı ile ilişkili olduğunu savunmaktadır. Bu bağlamda ötekinin silinmesi, çatışmanın ortadan kalkması değil; farklılıkla kurulan ilişkinin zayıflaması anlamına gelmektedir. Sonuç olarak çalışma, dijital kültürün çoğulculuk iddiasını eleştirel bir perspektifle yeniden düşünmeye davet etmektedir.

Anahtar Kelimeler: Dijital toplum, dijital kültür, öteki, algoritmalar, yankı odaları.

ERASING THE OTHER IN DIGITAL CULTURE: THE PROLIFERATION OF THE SAMENESS AND THE LOSS OF NEGATIVITY

ABSTRACT

Late modern society, under the influence of digitalization, claims to offer unlimited communication and pluralism. Social media platforms and algorithmic content flows create the

impression of a public sphere in which different opinions and identities become visible. However, this apparent plurality does not always strengthen the possibility of genuine encounters with difference. Byung-Chul Han argues in his work *The Expulsion of the Other* that one of the fundamental crises of contemporary society is the “loss of the Other.” According to Han, modern culture neutralizes and renders the different ineffective not through open exclusion or conflict, but through the production of sameness. Thus, the Other is not directly expelled but rather invisibly erased.

This study examines Han’s concepts of the “loss of negativity,” the “proliferation of the same,” and “narcissistic closure” from a sociological perspective within the context of digital culture. In particular, algorithmic personalization mechanisms, content recommendation systems, and echo chambers increase the likelihood that individuals encounter similar views and content, thereby limiting the experience of encountering difference. In digital environments, practices such as “following” and “blocking” also enable the rapid exclusion of content that disrupts users’ comfort. This process produces a homogenizing cultural structure rather than an overt form of repression.

The study argues that the tendency toward sameness in digital culture is not merely the result of technical algorithms, but is also related to the subject’s search for comfort and a self-oriented closure. In this context, the erasure of the Other does not signify the disappearance of conflict, but rather the weakening of the relationship with difference. Ultimately, the study invites a critical reconsideration of the claim of pluralism in digital culture.

Keywords: Digital society, digital culture, the Other, algorithms, echo chambers.

1. Giriş

Geç modern toplum, dijitalleşmenin etkisiyle iletişim imkânlarının genişlediği ve çoğulculuğun görünür hâle geldiği bir toplumsal bağlam üretmektedir. Sosyal medya platformları, algoritmik içerik akışları ve çevrim içi etkileşim ağları, farklı kimliklerin, görüşlerin ve yaşam tarzlarının aynı kamusal alanda temsil edildiği izlenimini güçlendirmektedir. Bu durum ilk bakışta toplumsal çeşitliliğin artması ve farklı olanla karşılaşma imkânlarının genişlemesi olarak yorumlanabilir. Ancak dijital kültürün sunduğu bu görünür çoğulluk, her zaman gerçek bir karşılaşma deneyimi üretmemekte; aksine benzerlik temelli yeni ayrışma biçimlerini de beraberinde getirebilmektedir.

Dijital ortamlarda bireylerin maruz kaldıkları içeriklerin büyük ölçüde algoritmik kişiselleştirme mekanizmaları tarafından belirlenmesi, farklı olanla temasın sınırlandırılmasına yol açabilmektedir. İçerik öneri sistemleri, yankı odaları ve filtre balonları, bireylerin

çoğunlukla kendi görüşlerine yakın içeriklerle karşılaşmalarını sağlamakta; bu durum ise toplumsal farklılığın deneyimlenmesini zorlaştırmaktadır. Bunun yanında çevrim içi platformlarda yaygınlaşan “takip etme”, “engelleme” ve “sessize alma” gibi pratikler de konfor bozucu içeriklerin hızla dışlanmasına imkân tanıyarak homojenleşmiş etkileşim alanları üretmektedir. Böylece dijital kültür, açık bir baskı mekanizmasından ziyade gönüllü benzerlik üretimi üzerinden işleyen yeni bir toplumsal düzenin oluşumuna katkıda bulunmaktadır.

Bu bağlamda çağdaş filozof Byung-Chul Han, modern toplumun temel krizlerinden birinin “ötekinin kaybı” olduğunu ileri sürmektedir. Han’a göre günümüz kültürü farklı olanı doğrudan çatışma yoluyla dışlamak yerine benzerlik üretimi yoluyla etkisizleştirmekte ve görünmez kılmaktadır (H Bu çalışma, Han’ın öne sürdüğü “negatifliğin kaybı”, “aynının çoğalması” ve “narsisistik kapanma” kavramlarını dijital kültür bağlamında sosyolojik bir perspektifle ele almayı amaçlamaktadır. Araştırmanın temel sorusu, dijital kültürün sunduğu görünür çoğulluğun, toplumsal farklılıkla kurulan gerçek karşılaşma deneyimini güçlendirip güçlendirmediyi ya da ötekinin görünmezleşmesine zemin hazırlayıp hazırlamadığıdır.

2. Kuramsal Çerçeve: Byung-Chul Han’da Ötekinin Kaybı

Geç modern toplumun kültürel dinamiklerini ele alan çağdaş düşünürlerden biri olan Byung-Chul Han, modernliğin yeni krizlerini “ötekinin kaybı” kavramı üzerinden tartışmaktadır. Han’a göre günümüz toplumu, farklılıkla kurulan çatışmalı ve üretken ilişkinin zayıfladığı; bunun yerine benzerlik temelli bir kültürel düzenin güç kazandığı bir döneme işaret etmektedir. Bu bağlamda Han, özellikle Ötekini Kovmak adlı eserinde, çağdaş kültürde farklı olanın doğrudan dışlanmaktan çok görünmez hâle getirildiğini ileri sürmektedir. Ona göre modern özne, ötekiyle karşılaşmanın yarattığı gerilim ve olumsuzluk deneyiminden kaçınarak kendisine benzer olanla temas etmeyi tercih etmektedir (Han, 2023).

Han’ın düşüncesinde bu dönüşümün temelinde “negatifliğin kaybı” yer almaktadır. Negatiflik, bireyin kendisi dışındaki olanla karşılaşması, sınırlarıyla yüzleşmesi ve farklılık üzerinden dönüşüm yaşaması anlamına gelmektedir. Ancak performans ve konfor odaklı çağdaş kültürde bu tür karşılaşmalar giderek daha az tercih edilmekte; özne, çatışma ve gerilimden arındırılmış bir deneyim alanı inşa etmeye yönelmektedir. Bu durum Han’ın “aynının çoğalması” olarak adlandırdığı süreci beraberinde getirmektedir. Toplumsal ilişkilerde benzerlik arayışı, farklılıkla kurulan ilişkinin zayıflamasına ve kültürel homojenleşmeye yol açmaktadır. Han ayrıca bu süreci “narsisistik kapanma” kavramıyla açıklamaktadır. Narsisistik özne, kendi benzerlerini çoğaltarak kendisini onaylayan bir etkileşim alanı yaratmakta; bu durum ise gerçek anlamda ötekiyle karşılaşma imkânını sınırlamaktadır. Böylece öteki, açık bir

yasaklama ya da dışlama mekanizmasıyla değil; görünmez kılınarak etkisizleştirilmektedir. Han'a göre çağdaş toplumun şeffaflık, performans ve sürekli olumlama kültürü de negatifliğin ortadan kalkmasına katkıda bulunarak farklılığın toplumsal işlevini zayıflatmaktadır (Han, 2023).

Bu çerçevede Han'ın yaklaşımı, dijital kültürde gözlenen benzerlik üretimi ve konfor alanı inşası pratiklerini anlamak açısından önemli bir kuramsal zemin sunmaktadır. Özellikle algoritmik kişiselleştirme mekanizmaları, bireylerin kendi görüşlerine yakın içeriklerle karşılaşma olasılığını artırarak farklılıkla temas deneyimini sınırlandırmakta; böylece ötekinin doğrudan dışlanmasından çok görünmez biçimde silinmesine zemin hazırlamaktadır (Han, 2023)

3. Dijital Kültürde Ötekinin Silinme Mekanizmaları

Dijital kültür, bireylerin farklı görüş ve kimliklerle karşılaşma imkânlarını teorik olarak genişletmekle birlikte, pratikte benzerlik temelli etkileşim alanlarının güçlenmesine de zemin hazırlamaktadır. Bu durumun oluşumunda algoritmik kişiselleştirme mekanizmaları, platform tasarımları ve kullanıcı pratikleri birlikte etkili olmaktadır. Böylece ötekinin silinmesi yalnızca teknolojik bir sonuç değil; aynı zamanda kültürel ve öznel yönelimlerle ilişkili bir süreç olarak ortaya çıkmaktadır.

3.1. Algoritmik Kişiselleştirme ve Yankı Odaları

Sosyal ağ platformlarında içerik akışı büyük ölçüde yapay zekâ temelli algoritmalar aracılığıyla düzenlenmektedir. Bu algoritmalar, kullanıcıların dijital davranışlarını izleyerek kapsamlı veri setleri oluşturmaktadır. Kullanıcıların paylaşımları, beğenileri, takip ettikleri hesaplar ve ziyaret ettikleri internet siteleri gibi etkileşimleri analiz edilerek kişisel ilgi alanlarına yönelik içerik öneri sistemleri geliştirilmektedir. Böylece algoritmalar, bireylerin platform kullanım sürelerini, içerik tercihlerini ve etkileşim örüntülerini dikkate alarak onlara daha çok ilgilerini çekmesi muhtemel sosyal medya hesaplarını ve içerikleri sunmaktadır (Digipeak, 2021).

Bu süreçte sosyal medya platformları, kullanıcıların hangi içerikleri tükettiklerine dair elde ettikleri verileri ekonomik bir değere dönüştürmektedir. Kullanıcı ilgisi ve dikkatinin platformda tutulması, hedeflenmiş reklam stratejileriyle doğrudan ilişkilendirilmekte ve bu sayede platformlar reklam gelirlerini artırmaktadır (Andı, 2021: 2).

Dijital platformlarda içerik akışı büyük ölçüde kullanıcı tercihleri, geçmiş etkileşimler ve davranışsal veriler üzerinden şekillenmektedir. İçerik öneri sistemleri, bireylere ilgi alanlarına ve görüşlerine yakın içerikler sunarak platformda geçirilen süreyi artırmayı hedeflemektedir. Bu durum, farklı olanla karşılaşma ihtimalini azaltarak benzerlik üretimini

güçlendirmektedir. (Hassani vd., 2025) Literatürde “yankı odası” ve “filtre balonu” kavramlarıyla açıklanan bu süreç, bireylerin çoğunlukla kendi düşüncelerini teyit eden içeriklerle karşılaşmalarına yol açmaktadır. Böylece dijital kamusal alan, görünürde çoğulcu olsa da deneyim düzeyinde homojenleşmiş etkileşim alanlarına dönüşebilmektedir.

Yankı odası etkisi bağlamında internet ortamı, kullanıcıların hoşlanmadıkları ya da kendi görüşleriyle örtüşmeyen mesajları filtreleyebilmelerine imkân tanımakta ve bu durum bireylerin kendi dijital etkileşim alanlarını benzer görüşler etrafında şekillendirmelerine yol açmaktadır. Böylece kullanıcılar çevrim içi ortamda karşıt düşüncelere giderek daha az maruz kalmakta; homojen gruplar içinde yalnızca kendi bakış açılarını destekleyen internet kaynaklarını ve sosyal medya hesaplarını takip etmeye yönelmektedir (Colleoni ve ark., 2014: 319). İlk aşamada bilgiye erişimi kolaylaştıran ve daha işlevsel görünen bu seçici maruz kalma pratiği, zamanla “grup kutuplaşması”nın derinleşmesine neden olabilmektedir (Sunstein, 2004: 59).

Bunun ötesinde internet ortamı, benzer görüşteki bireylerin birbirleriyle daha yoğun etkileşim kurmasına olanak sağlayarak kutuplaşma eğilimlerini güçlendirebilmektedir (Liao ve Fu, 2014: 184). Bu süreçte kullanıcılar, dijital platformlar aracılığıyla kendi “sanal kabilelerini” oluşturarak benzerlik temelli etkileşim ağları içinde konumlanmakta ve giderek homojenleşen bir iletişim çevresinin etkisi altında kalabilmektedir.

“Filtre balonu” kavramı, çevrim içi kişiselleştirmenin bireyleri farklı bakış açıları ve içeriklerden izole etme potansiyelini ifade etmek üzere ilk kez Eli Pariser (2011) tarafından kullanılmıştır (Nguyen ve ark., 2014: 677). Bu kavram, Facebook ve Twitter gibi sosyal ağ platformlarında kullanıcıların kendi siyasal eğilimleri ve ilgi alanlarıyla uyumlu içeriklerle çevrelenerek kişiselleştirilmiş geri bildirim döngüleri içinde konumlanma eğilimini açıklamaktadır (Hess, 2017). Filtre balonu yaklaşımı, algoritmik olarak özelleştirilmiş içerik akışlarının bireylerin farklı görüş ve perspektiflerle karşılaşma olasılığını azaltabileceğini ve bu durumun aşırı kişiselleştirme bağlamında çeşitli toplumsal ve bilişsel riskler barındırdığını vurgulamaktadır.

3.2. Konfor Alanı Pratikleri: Takip Etme ve Engelleme Kültürü

Dijital platformlar, kullanıcıya etkileşim alanını aktif biçimde düzenleme imkânı sunmaktadır. “Takip etme”, “engelleme”, “sessize alma” ve benzeri pratikler, bireylerin konfor bozucu içerikleri hızlı biçimde dışlamasına olanak tanımaktadır. Bu durum, açık bir sansür mekanizmasından ziyade gönüllü bir ayrışma biçimi üretmektedir. Kullanıcılar çoğu zaman çatışma, gerilim ve farklılık deneyimi yerine benzerlik ve onay arayışını tercih etmektedir.

Böylece ötekiyle karşılaşma, toplumsal öğrenme ve empati geliştirme açısından taşıdığı dönüştürücü potansiyeli kaybetmektedir.

3.3. Görünürlük Ekonomisi ve Performans Temelli Benlik Sunumu

Dijital kültürde görünürlük, önemli bir toplumsal sermaye biçimi hâline gelmiştir. Beğeni, paylaşım ve takipçi sayısı gibi ölçülebilir göstergeler, bireylerin çevrim içi varlıklarını performatif bir biçimde düzenlemelerine yol açmaktadır (Erden, 2025). Bireyler dijital ortamlarda sahip oldukları sermaye türlerini görünür kılma ve bu görünürlüğü toplumsal tanınma ile değere dönüştürme yönünde aktif bir çaba içindedir. Sosyal medya, sermayenin yalnızca biriktirildiği bir alan olmanın ötesinde, performatif biçimde sunulduğu, sürekli güncellendiği ve çeşitli anlatı stratejileriyle anlamlandırıldığı bir sahne işlevi görmektedir. Kullanıcılar ekonomik sermayelerini yaşam tarzı pratikleri ve tüketim tercihleri üzerinden yansıtırken; kültürel sermayelerini entelektüel uğraşlar, sanatsal faaliyetler ve bilgiye dayalı paylaşımlar aracılığıyla sergilemektedir. Sosyal sermaye, kurulan ilişkiler ağları ve ait olunan çevreler üzerinden görünürlük kazanırken; sembolik sermaye ise ödüller, akademik ya da mesleki unvanlar ve otorite figürleriyle kurulan temaslar üzerinden meşrulaştırılmaktadır. Bu çok katmanlı sunumlar, medyatik estetik kodlarla yeniden biçimlendirilerek dikkat çekici, gösterilebilir ve dolaşıma açık içeriklere dönüştürülmektedir. Böylece sosyal medya, bireylerin yalnızca dijital temsillerini kurdukları bir platform değil; aynı zamanda farklı alanlarda sahip oldukları sermayeleri teyit ettikleri ve yeniden ürettikleri stratejik bir görünürlük alanına dönüşmektedir (Güneş ve Kök, 2025). Bu bağlamda kullanıcılar, daha fazla kabul görmek ve görünürlük elde etmek amacıyla çoğunlukla normatif ve güvenli içerikler üretmeye yönelmektedir. Farklı ya da riskli olarak algılanabilecek söylemler ise etkileşim kaybı korkusuyla geri planda bırakılabilmektedir. Suskunluk Sarmalı Kuramı (Noelle-Neumann, 1974), bireylerin sosyal dışlanma ihtimali karşısında düşüncelerini geri çekme eğilimlerini açıklayan önemli bir çerçeve sunmaktadır. Dijital kültürde bu durum, kullanıcıların etkileşim kaybı ya da görünürlük azalması riskini minimize etmek amacıyla daha güvenli ve yaygın kabul gören benlik temsillerini tercih etmelerine yol açabilmektedir. Böylece çevrim içi kimlik sunumu, yalnızca performatif bir strateji değil; aynı zamanda algılanan çoğunluk normlarına uyum sağlama pratiği hâline gelebilmektedir. Bu durum, dijital ortamda idealize edilmiş benlik temsillerinin yaygınlaşmasına ve kültürel benzerlik üretiminin hızlanmasına katkıda bulunmaktadır.

Sonuç olarak dijital kültürde ötekinin silinmesi, yalnızca algoritmaların teknik işleyişiyle açıklanabilecek bir olgu değildir. Bu süreç, bireylerin konfor arayışı, onay ihtiyacı

ve performans baskısıyla şekillenen öznel yönelimleriyle birlikte anlaşılmalıdır. Böylece farklılıkla kurulan ilişki, açık çatışma ya da dışlama biçiminde değil; görünmezleşme ve temasın zayıflaması üzerinden dönüşmektedir.

4. Sosyolojik Sonuçlar: Karşılaşmanın Zayıflaması ve Ahlaki Duyarlılığın Dönüşümü

Dijital kültürde ötekinin görünmezleşmesi, yalnızca iletişim biçimlerinin dönüşümüyle sınırlı olmayan daha geniş sosyolojik sonuçlar doğurmaktadır. Farklılıkla kurulan temasın azalması, bireylerin empati geliştirme ve toplumsal çeşitliliği deneyimleme imkânlarını sınırlandırmaktadır. Karşılaşmanın zayıflaması, toplumsal ilişkilerin yüzeyselleşmesine ve benzerlik temelli etkileşim ağlarının güçlenmesine yol açabilmektedir. Bu durum, kamusal tartışma kültürünün daralması ve farklı görüşlerin bir arada var olma kapasitesinin zayıflaması açısından dikkat çekici bir dönüşüme işaret etmektedir. Öte yandan dijital ortamlarda çatışmanın görünür biçimde yaşanmaması, toplumsal gerilimlerin ortadan kalktığı anlamına gelmemektedir. Aksine farklılıkla kurulan ilişkinin görünmezleşmesi, bireylerin kendi yankı alanlarında kapanarak alternatif perspektiflere karşı daha az tolerans geliştirmelerine neden olabilmektedir. Böylece farklı olanla yüzleşme deneyiminin yerini, benzer olanla sürekli karşılaşma pratiği almaktadır. Bu durum, toplumsal öğrenme süreçlerini sınırlandırdığı gibi bireylerin eleştirel düşünme kapasitesini de zayıflatabilmektedir.

Geleneksel toplumsal bağlamlarda ötekiyle yüz yüze temas, etik duyarlılığın gelişmesinde önemli bir rol oynamaktadır. Ancak dijital ortamda farklı olanın filtrelenmesi ve görünmezleşmesi, bireyin öteki karşısındaki sorumluluk bilincini daha performatif ve yüzeysel bir düzleme taşıyabilmektedir. Böylece ahlaki duyarlılık, doğrudan karşılaşma deneyiminden ziyade sembolik ve dolaylı etkileşim biçimleri üzerinden şekillenmektedir.

5. Sonuç

Bu çalışma, dijital kültürde ötekinin silinmesi olgusunu Byung-Chul Han'ın kuramsal çerçevesi üzerinden sosyolojik bir perspektifle tartışmıştır. Bulgular, dijital platformların sunduğu görünür çoğulluk imkânına rağmen algoritmik kişiselleştirme mekanizmaları ve kullanıcıların konfor odaklı etkileşim pratikleri aracılığıyla benzerlik temelli iletişim alanlarının giderek güçlendiğine işaret etmektedir. Bu durum, farklılıkla kurulan doğrudan temasın zayıflamasına ve ötekinin açık bir dışlama sürecinden çok görünmezleşme yoluyla etkisizleşmesine zemin hazırlamaktadır.

Bu bağlamda dijital kültürde çoğulculuk, niceliksel içerik çeşitliliği ile sınırlı bir görünürlük artışı olarak değil; karşılaşma deneyiminin niteliği üzerinden yeniden değerlendirilmelidir. Farklı olanın yasaklanmadığı, ancak temasın seyrelmesi yoluyla etkisizleştirildiği bu kültürel yapı, toplumsal öğrenme süreçlerini, empati kapasitesini ve etik

duyarlılık biçimlerini dönüştürmektedir. Böylece dijitalleşme, yalnızca iletişim teknolojilerinin gelişimi olarak değil; öznenin yeniden kurulması, tanınma mücadeleleri ve karşılaşma pratiklerinin dönüşümü bağlamında eleştirel sosyolojik analizlerin merkezine yerleşmektedir.

Sonuç olarak ötekinin silinmesi, dijital kamusal alanda farklı görüşlerin tamamen ortadan kalkmasından ziyade, öznenin kendi yankı alanı içinde kapanması ve toplumsal karşılaşma kapasitesinin giderek daralmasıyla ilişkilidir. Bu nedenle dijital çağda çoğulculuğun sürdürülebilirliği, farklılıkla kurulan gerçek temasın hangi koşullarda mümkün olabileceğine dair yeni tartışmaları zorunlu kılmaktadır.

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THE ECONOMIC, LEGAL AND SOCIAL EFFECTS OF THE OLIGOPOLISTIC STRUCTURE IN THE MOBILE TELEPHONY MARKET IN ALBANIA

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ABSTRACT

The telecommunications market, as a market linked to and influenced by technology, has, over the last 30 years, transformed telecommunications companies into key actors and factors in today's digital world, on a global scale.

The paper analyzes the return of the oligopolistic structure in the mobile telephony market in Albania and the effects that this structure produces on competition, price transparency and consumer protection. The price of products and services offered by mobile operators and companies is a complex function of many capital, operational and regulatory costs, as well as competition parameters, which are transferred to the final consumer. The consolidation of operators and the reduction of the number of entities active in the market have led to the weakening of competitive pressure, favoring coordinated behavior and commercial practices that limit real consumer choice.

Economic and legal analysis shows that oligopoly is associated with increased costs for end users, reduced competitive offers and the spread of not fully transparent prices, including hidden fees and complex contractual conditions. In this context, the paper also assesses the role of regulatory authorities and the effectiveness of the legal framework in supervising the market and ensuring effective consumer protection.

The paper concludes that the return to oligopoly in the mobile telephony sector is producing negative effects on the functioning of the market and consumer welfare, highlighting the need to strengthen regulatory policies, increase price transparency and promote fair competition in the sector.

Keywords: *Oligopoly, structure, hidden prices, effects, legal framework, telephony market in Albania*

1. INTRODUCTION

The telecommunications market, closely linked to and influenced by technology, has gone through several phases of transformation in recent years, transforming telecommunications companies into key actors and factors of today's digital world, interconnected on a global scale. In fact, this industry has faced many challenges over the years, where technological developments have undoubtedly strongly remodeled not only the approach to the market, but also the business model. The performance and development of the mobile telephony market has always been and remains an important issue regarding the price of services and products offered by operators, telecommunications companies. Mobile telephony companies remain the most criticized in the public, in terms of the level of prices applied to their products. In the vast majority of cases, this problem has come and comes mainly from the lack of information, the suboptimal level of transparency towards the public, or overly technical communication on the part of the mobile operators themselves. In this market, it is a fact that there is no public information about the final prices for the products and services of these companies. In no communication channel, media or portal and website, are simple and easily understandable explanations given, related to the elements that shape the final price of these services.

The paper analyzes recent developments in the mobile telephony market in Albania, focusing on the return of the oligopolistic structure, specifically duopolistic, a form of oligopoly, as well as the economic, legal and social effects that this structure produces on competition and consumer welfare. The duopolistic situation according to Romeo, Giovanni (2019) has to do with “the existence of only two sellers where the action of each firm affects the demand faced by its rival and high barriers to entry are often present, making it difficult for new firms to enter the market”.

The rapid and complex developments of the last 20 years, not only in the international economy and market, but also in the Albanian one, have demonstrated different realities and management and business philosophies for Albanian telecommunications companies, mainly mobile ones. Thus, while the market at the peak of its development recognized the presence of 4 operators (a special and unusual situation for the modest size of the Albanian market and the consequences for the optimal level of development of this business), the economic reality and strong competition resulted in the exit of the smaller operator from the market and the continuation of the (profitable) business of the large operators, where Vodafone undoubtedly still remains the largest operator in the market, as it has been for the vast majority of the time, with over 51% of the market. As a result, the consolidation of companies and the reduction of

the number of active operators has led to a market dominated by two powerful entities where the prices of communication services in Albania are among the highest in Europe.

According to data from the Electronic and Postal Communications Authority (AKEP, 2023), total internet traffic from mobile networks increased by 13.2% compared to the second quarter of last year. Average internet consumption per user reached 9.84 GB (gigabytes) of internet per month, an increase of 11.2% compared to the same period a year earlier. In total, the two mobile operators earned approximately 1.68 billion lek for 2024, while the year 2023 was closed with a net profit of 370 million lek. With this figure, the two mobile operators have achieved the highest profit since 2019. The increase in communication service prices following the market concentration of two single operators is positively affecting the operators' revenue base and increasing their profits.

The study highlights that the return to oligopoly has led to an increase in real service prices, a restriction of promotional offers and an increase in non-transparent pricing practices, including hidden fees and complex contractual terms. These phenomena weaken the bargaining power of consumers and reduce the possibility of real choice in the market. From an economic point of view, the analysis shows that oligopoly encourages coordinated behavior among operators, reducing competitive pressure and creating entry barriers for new actors. In the legal aspect, the paper assesses the role of regulatory and institutional authorities, emphasizing the need for strengthening competition supervision and more effective implementation of consumer protection legislation. In the social dimension, the study highlights the negative impact on vulnerable groups and low-income users, who are most affected by rising costs and the lack of clear information on services. The analysis shows that, despite the existence of a legal framework harmonized with European Union standards, practical implementation remains limited, allowing oligopolistic behavior to persist. In conclusion, the paper argues that the return to oligopoly in the mobile telephony sector is producing negative effects on the functioning of the market and consumer welfare, highlighting the need for more active regulatory policies, increased price transparency and a strengthened role of consumer protection institutions. The study argues that the solution to the problems of oligopoly in the Albanian mobile telephony market does not lie only in the numerical growth of operators, but in the creation of a regulatory and competitive environment that empowers the consumer, promotes real competition and guarantees the efficient functioning of the market.

2. Literature Review

The mobile phone market is a global industry that is a fundamental part of modern technological progress and development. It represents the global communication without which society cannot do. When the structure of the mobile phone market is highly concentrated, we are dealing with an oligopolistic market, where a few large players command a large share of the market. Through this structure, the telecommunications industry experiences low competition with high market power dominated by a few organizations.

The study focuses on the oligopoly of the mobile phone industry. It shows the degree of concentration and how the exercise of this power affects prices, the introduction of new products and consumer decisions. “An oligopoly market structure occurs when a few large sellers dominate an industry” (Pindyck & Rubinfeld, 2001 p. 446). In an oligopolistic market, many firms are interconnected, meaning that a decision made by one company can have a ripple effect on others. Understanding these dynamics can help assess market behavior and the potential for collusion or other actions that could be harmful to consumers. The law of supply and demand best explains supply and demand economics. The law of demand states that as the price of a good increases, the demand for that good decreases, and when the price of a good decreases, the demand for that good increases. The law of supply states that as the price of a good increases, the supply of that good increases, and as the price decreases, the supply of the good decreases. Both demand and supply are a direct function of price. We examine how structural changes in the mobile telecommunications industry, when local markets are duopolies, affected operators' product offerings and nonlinear pricing strategies.

Oligopoly models, in the international literature, are analyzed as the most common form of organization in telecommunications sectors due to high fixed costs and entry barriers. Economic theories suggest that oligopoly can lead to coordinated pricing behavior, restriction of innovation, and reduced consumer welfare due to the lack of effective competition, especially when there are no new operator entries and the absence of active regulatory policies in the market. Theoretical analyses of price dynamics and competition under oligopoly use Bertrand, Cournot, and strategic behavior of operators as frameworks to understand mobile market performance. The Cournot and Bertrand models are two basic models of oligopolistic competition and explain how firms behave when there are few in the market. (Cournot, A. A. .1838), first formulated the model of oligopolistic competition where firms compete through the quantity of production and not through price, laying the foundations of the modern theory

of industrial organization. Bertrand, J. (1883). criticized the Cournot model and proposed price competition, demonstrating that firms compete directly through price.

2.1 Economic effects of the oligopolistic structure in mobile telephony

The economic literature on oligopoly argues that markets with few operators are characterized by high concentration, strategic behavior, and low competitive pressure, which is often reflected in higher prices and lower efficiency for the consumer (Carlton & Perloff, 2015; Motta, 2004). In the telecommunications sector, these effects are reinforced by high fixed costs and structural entry barriers (Laffont & Tirole, 2000). International empirical studies show that the reduction in the number of mobile operators is associated with increased tariffs and a slowdown in innovation (Houngbonon & Jeanjean, 2016; Gruber, 2017). In the Albanian context, AKEP reports and economic market analyses show that the consolidation of operators has led to a duopolistic/oligopolistic structure, with a direct impact on the level of prices and service packages (AKEP, 2022; AKEP, 2023). INSTAT reports and market analyses show that consumer spending on communication services remains relatively high compared to average income, suggesting an inefficient distribution of economic benefits under oligopoly conditions (INSTAT, 2022; Monitor, 2023). This study, which focuses on oligopoly in the electronics industry, is important because it shows the degree of concentration and how the exercise of this power affects prices, new product introductions, and consumer decisions. In an oligopolistic market, more firms are interconnected, meaning that a decision made by one company can have a ripple effect on others. Understanding these dynamics can help assess market behavior and the potential for collusion or other actions that could harm consumers. As a result, this study has implications for business and society. It can help marketers and industry regulators formulate policies to avoid monopolistic practices and promote competition. Therefore, the effects of oligopoly become important for business students because they provide insights into the behavior of industries and the decision-making processes of organizations, ranging from individual pricing to overall strategies such as acquisitions. Ideologically, this research can reveal the availability and cost of consumer electronics, so that innovations can be extended to the majority of the public. In addition, the use of optimization methods can propose ideas on ways to increase market efficiency, develop product quality, and promote sustainability in the business world.

2.2 Legal and regulatory effects of oligopoly in Albania

From a legal perspective, the literature on competition policy emphasizes that oligopolistic markets require active regulatory intervention to prevent abuse of dominant position and coordinated behavior (Motta, 2004; OECD, 2019). In the telecommunications sector, regulation is essential to guarantee fair access and protect the public interest (European Commission, 2020).

In Albania, the legal framework for competition and consumer protection exists, but the literature and institutional reports indicate difficulties in its effective implementation in the mobile market. The Competition Authority has identified the risk of coordination of behavior among major operators and has undertaken investigations into potentially anti-competitive behavior (Competition Authority, 2022; 2023). Audits of the Supreme State Control and regulatory reports emphasize that the oligopolistic structure limits the effectiveness of existing legal instruments, especially with regard to price transparency and contractual conditions for consumers (KLSH, 2021; AKEP, 2023).

2.3 Social effects and consumer protection

These firms have significant market control, which enables them to control prices, offers and all market forces. These companies achieve large market shares, therefore, they are able to set prices relatively higher or relatively lower than those set in a competitive market. For example, the strategic use of high prices by Vodafone Albania and One Albania for their products has an integrated customer base where they focus their loyalty, hence high profit margins. The consumer protection literature highlights that oligopolistic markets are often associated with information asymmetry, non-transparent practices and increased financial burdens for vulnerable groups (OECD, 2020; UNCTAD, 2017). In the mobile telephony sector, these effects manifest themselves through hidden fees, complex packages and difficulties in comparing offers.

In the Albanian reality, studies and reports show that consumers have limited knowledge of their rights and are often faced with standard contracts that favor operators (European Parliament, 2020; Monitor, 2022). The oligopolistic structure reduces real opportunities for operator switching, weakening consumer bargaining power and negatively affecting social welfare. In this context, the literature suggests that strengthening price transparency and consumer education are key elements for mitigating the negative social effects of oligopoly (OECD, 2020; UNCTAD, 2017). To improve consumer decision-making, organizations need

personalization to ensure customer satisfaction and brand loyalty, as the products offered can be customized according to customers' needs and preferences.

2.4 Mobile market structures in Albania

According to the empirical literature, the telecommunications market, as a market, linked to and influenced by technology, has gone through several phases of revolutionary transformations over the last 30 years:

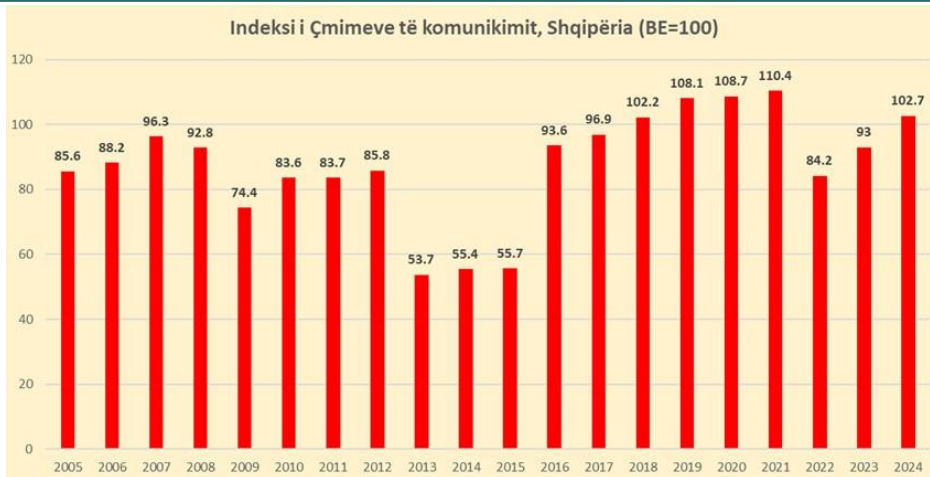
Phase one: Period with more competitors: In the first years of liberalization, the market consisted of four major operators, where the entry of Eagle Mobile and Plus Communication brought an increase in competition and a decrease in prices.

Phase two: Exit of competitors and consolidation: Plus Communication exited the market in 2018, while the ownership structures changed when Albtelecom was acquired by the 4iG group and merged with One Albania. This led to the dominance of the two main operators, Vodafone Albania and One Albania, creating a practical duopoly in the Albanian mobile market.

Phase three: Current duopoly/oligopoly structure: Recent data show that the market is effectively dominated by two main players, with high market concentration and the main service packages controlled by these players.

2.5 Empirical evidence on prices and competition in Albania

Many reports and studies have documented an increasing trend in the prices of mobile telephony services and the real costs for the Albanian consumer. The prices of communication services in Albania are among the highest in Europe, according to the latest data from Eurostat. "The price index for 2023 resulted 2.7% above the European Union average, confirming an increasing trend that has particularly affected mobile telephony users. The mobile market in the country has returned to the monopoly of two operators, a structure not seen since 2008." This indicator of communication services in Albania is a possible indicator of the effects of reduced competition and market concentration.



Sources: Eurostat, Monitor.

Data from AKEP shows that there is an increase in user spending in 2023, where an average user spent about 7900 lek on mobile services, with an increase of 16% compared to the previous year. There was also an increase in the cost per minute of call. According to the AKEP report, in 2023 each minute of call cost an average of 4.78 lek, an increase of 27% compared to the previous year. While prices for citizens have increased, operators have achieved profits. While citizens pay high prices, for offers with limited services, the two main operators of the market realized a total profit of 619 million lek. Another problem remains contracts, which force citizens to receive services even if they no longer need them or otherwise pay hefty fines to telephone operators. The Supreme State Audit Office has reported that Albania ranks among the countries with the highest tariffs compared to other European countries, suggesting a connection between the oligopoly structure and the real prices of services. The Albanian authorities have reacted to these developments, with the Competition Authority launching a preliminary investigation and then an in-depth investigation into the conduct of the main operators in the mobile market, examining possible violations of the law on the protection of competition as a result of market concentration. The Competition Authority has identified the risks associated with duopoly structures and has stressed the need for legal changes that enable more effective interventions to protect competition, suggesting that a market with two large players may encourage coordinated behavior that harms consumers. The Competition Authority has invited consumers and interested parties to report harmful practices, integrating the voice of the consumer in the competition monitoring process. While there are statistical analyses and reports from regulatory institutions, specialized academic literature on the effects of the oligopolistic structure on mobile telephony in Albania is still relatively limited compared to other European countries. Existing studies focus mainly on marketing strategies and consumer

perception in the Albanian market, of an earlier period with more players and on the efficiency of the legal framework, as in the case of “number portability and regulatory barriers to competition” (Gjika, Bushati, 2023). In the Albanian context, AKEP reports and economic market analyses evidence that the consolidation of operators has led to a duopolistic/oligopolistic structure, with a direct impact on the level of prices and service packages (AKEP, 2022; AKEP, 2023). INSTAT reports and market analyses show that consumer spending on communication services remains relatively high compared to average incomes, suggesting an inefficient distribution of economic benefits under oligopoly conditions (INSTAT, 2022; Monitor, 2023).

3.Methodology

The research methodology includes a number of activities that need to be carried out. According to Howell (2012), the methodology describes “the overall research strategy that determines how the research is conducted”. For this reason, one of the first steps in planning a research process is “a literature review, which involves searching all sources of information to track the latest knowledge, assessing its relevance to our topic, quality, contradictions and gaps”. This study is based on qualitative analysis of secondary data, including official institutional reports, legal documents and academic literature. Secondary research is a collection of work that has been done and published by some researchers in the field, which is available for others to use in their study. Secondary data sources can be collected from various sources such as books, journals, official bulletins etc. This paper uses a qualitative analytical approach, combined with comparative elements, to analyze the economic, legal and social effects of the oligopolistic structure in the mobile telephony market in Albania. The study is mainly based on: Systematic review of international academic literature on oligopoly theory, competition in telecommunications and consumer protection; Analysis of official documents and institutional reports of national authorities (AKEP, Competition Authority, Supreme State Audit, INSTAT); Analysis of the Albanian legal and regulatory framework, in relation to European Union standards and practices. To connect the theory with the Albanian reality, the study uses comparative analysis with small European countries with similar market structures, identifying successful regulatory practices applicable in Albania. The data are analyzed through thematic analysis, categorizing the findings according to the three main dimensions of the study: economic, legal and social. This approach allows an integrated assessment of the impact of oligopolistic structure on competition, price transparency and consumer welfare. The methodological advantages relate to the adaptation to the lack of public microeconomic data,

ensuring coherence between theory and practice, and being suitable for policy and regulatory analysis. The main materials studied include AKEP annual reports, Competition Authority decisions, INSTAT data, as well as classical and contemporary literature on industrial organization (Cournot, 1838; Bertrand, 1883; Motta, 2004; Carlton & Perloff, 2015). OECD and European Commission reports on electronic communications markets and competition policies were used for the comparative analysis. The literature review included studies on oligopolistic structures and regulation of telecommunications markets, based on OECD (OECD, 2019; European Commission, 2020) and European Commission reports on competition in electronic communications markets, as well as on best practices of countries with small markets and structures similar to Albania. The legal analysis was carried out through a review of the Albanian regulatory framework for competition and electronic communications, including Law no. 9121/2003 “On the Protection of Competition”, Law no. 9918/2008 “On electronic communications”, as well as the relevant by-laws and institutional practices of the Competition Authority and AKEP. To assess the social dimension and impact on the consumer, reports on consumer protection, studies on information asymmetry and consumer behavior, as well as official documents on price transparency and standard contracts in the telecommunications sector were used. (OECD, 2018; European Consumer Organisation, 2021). The analysis is based on theoretical literature on oligopoly, national and European institutional reports, as well as empirical data on the Albanian mobile telephony market.

The study uses secondary data, which may limit the depth of examination and the reliability of the data. Secondary data may be incomplete, include old data, or be influenced by researcher bias, which affects the reliability of the results. This study attempts to provide a new understanding of how oligopoly affects the mobile phone market. By analyzing the consequences of market control and competition, actors will be able to adapt to existing trends and improve the situation. The results confirm that trends require strategic diversification and innovation, as well as compliance with regulations, thus fostering a more competitive environment.

4. Analysis of the study results

There are several main results of the study of oligopolistic influence in the mobile telephony market, focusing on Vodafone Albania and One Albania. The market control in the hands of these firms influences price levels and, therefore, this paper sees very little price flexibility and little or no competition. These few firms play the role of both enabler and inhibitor of innovation through their massive R&D expenditures necessary to independently drive innovation, while

protecting at the same time their superior positions in different markets from disruptive innovation. The economic analysis shows that the Albanian mobile telephony market is characterized by a high level of concentration and limited real competition. Operators exhibit typical oligopolistic behavior, where competition takes place mainly through packages and the quantity of services, reflecting elements of the Cournot model. Prices remain relatively stable and do not reflect strong competitive pressure, while price reductions are often formal or linked to promotional structures, without long-term sustainable impact. This situation limits the economic benefits of the consumer and encourages the maintenance of high profits for the existing operators. The legal analysis shows that Albania has a normative framework harmonized with the European Union standards in the field of competition and electronic communications. However, the results show a significant gap between the legal norm and practical implementation. Regulatory interventions are mainly reactive and limited to addressing the consequences, rather than preventing oligopolistic behavior. As a result, legal mechanisms fail to create sufficient pressure for effective price competition. The results of the social analysis show that the oligopolistic structure negatively affects the consumer's choice power. High loyalty to the existing operators, switching costs and information asymmetry limit the ability of consumers to benefit from alternative offers. Limited transparency of contracts and prices reinforces consumer uncertainty and increases the perception of a lack of real competition in the market.

The study includes a qualitative comparative analysis with countries with small markets and similar structures (e.g. Slovenia), to identify functional regulatory models, the role of MVNOs, policies that have brought real price reductions. This section serves as a basis for concrete policy recommendations, applicability in the Albanian context. The literature on industrial organization emphasizes that the number of operators is not a sufficient condition for effective competition (Motta, 2004; Carlton & Perloff, 2015). In the mobile telephony sector, fixed costs are very high, infrastructure is limited, and the market is relatively small (like Albania). This means that the formal entry of a new operator does not guarantee price reductions if the operator does not have real market weight, does not have fair access to infrastructure, and does not have the capacity to compete on prices. The addition of companies may not reduce prices because strategic behavior in oligopoly with even more operators allows companies to coordinate understanding on prices, avoid “price wars,” and maintain high profits. This is called tacit cooperation. Another factor is the structural barriers of the Albanian market, where in Albania we have a small market, so we have a limitation of the scale of the economy, dominance of the

two main operators, and difficulty for new operators to reach critical mass of customers. Small operators usually absorbed by the big ones, or exit the market (Plus Communication case). The effect of "satellite operators". A new operator often follows the leader's prices, does not really lower tariffs, serves only for competitive legitimacy, not real competition. The addition of operators affects the reduction of prices only if accompanied by structural policies such as the entry of MVNOs (Mobile Virtual Network Operators) that use the existing infrastructure, have lower costs, offer more aggressive prices. In many EU countries, MVNOs have reduced tariffs, increased competitive pressure. Strong regulation of access to infrastructure, functional separation of networks, equal access to the frequency spectrum, wholesale controlled tariffs. Mandatory price transparency consisting of a ban on hidden tariffs, standardization of packages, real comparability for the consumer. This activates competition on the demand side. Strengthening the Competition Authority, which is concerned with monitoring and coordination on price understanding, real penalties for anti-competitive behavior, proactive interventions, not just reactive ones.

4.1 What would work specifically in Albania?

A realistic and effective solution would be the entry of MVNO. Strong regulation of access to infrastructure would have effects on prices, therefore real reductions. Price transparency is essentially competitive pressure. Consumer education directly affects the strengthening of demand. Active antitrust investigations by inhibiting cooperation between operators. While only the addition of operators would have a limited effect on the real reduction of prices. In conclusion, the addition of companies to the mobile telephony market does not guarantee price reductions if it is not accompanied by structural regulatory reforms. In the conditions of an oligopolistic market like Albania, effective competition requires institutional intervention, price transparency and mechanisms that empower the consumer. The reality situation in the Albanian market can be solved by taking an example of success with conditions like Albania. Albania is not a unique case, and there are examples of success in countries with small markets, limited incomes and similar infrastructure. First of all, Albania needs "designed competition", not spontaneous. In small markets like Albania, competition does not arise by itself, oligopoly is a "natural" structure, the state and the regulator must design competition. This approach is used successfully in several countries with similar conditions. An example of comparable success is Slovenia where the population is approximately 2.1 million, small market, 2-3 dominant operators, very active regulator. Albania where the population is approximately 2.8 million, small market, 2-3 dominant operators, active regulator in development. Slovenia allowed and

strongly supported MVNOs, i.e. the entry of virtual operators (without a network), aggressive tariffs for consumers, targeting specific segments (students, families). As a result, there were price reductions and simpler packages. It strongly regulated network access, where dominant operators were forced to provide wholesale access, at regulated prices, without discrimination, and this reduced their structural advantage. It intervened against tacit coordination through active price monitoring, real penalties, and the publication of comparative reports for consumers, and the result was the breaking of "oligopolistic comfort." It empowered consumers by enabling online and official comparison of tariffs, standardized contracts, and a ban on hidden fees.

4.2 How can this model be applied in Albania?

First - MVNO entry as a national priority by changing the regulatory framework by AKEP, obligation for free access to the network, simplified licenses for MVNO. More effective than a classic new operator.

Second - Pre-service regulation, not just post-service punishment that is realized with prior regulation of wholesale prices, and not just investigations after price increases.

Third - Radical price transparency that is realized with legal prohibition of hidden fees, standard package structure, official price comparator.

Fourth - AKEP-Competition Authority cooperation that is realized with joint market monitoring, periodic analysis of cooperation risk, rapid institutional response.

This solution works for Albania because it does not require massive infrastructure investments, reduces prices without destabilizing the market, increases real consumer choice, is proven in small markets, and is consistent with EU practices. In small markets like Albania, competition is not created by adding traditional operators, but by designing a regulatory ecosystem that allows the entry of MVNOs, guarantees fair access to the network, and empowers the consumer. The Slovenian example shows that this approach reduces prices without jeopardizing market stability. Another important factor is consumer loyalty, which conditions that the entry of new operators does not guarantee real change. The literature on consumer behavior and oligopolistic markets shows that loyalty is not necessarily related to satisfaction, but to real and psychological switching costs, complex contracts and packages, fear of losing service, perception that "everyone is the same". In this context, a new operator does not win customers just by existing, but must offer visible and credible value. A new operator to bring about real change must offer an immediate and measurable difference in price, i.e. not a "slightly cheaper" package, but a visible reduction (20–30%), a very simple pricing structure because the customer

only switches when the profit is clear and fast. Radical transparency without hidden fees, one price - one service, no small conditions, no penalties hidden because this creates trust in the consumer, not just interest. Flexible contracts and no exit penalties (no long-term contracts, no exit and activation fees, simple deactivation), this significantly reduces the psychological cost of switching. Targeting neglected segments where existing operators focus on mass customers and standard packages while a new operator should focus on students, young people, low-budget families, digital users because the "niche market" strategy is more effective than frontal competition. Superior experience, not just price (simple application, real and fast support and clear communication) because the consumer leaves the existing operator more easily when the experience is significantly better. In oligopolistic markets with high consumer loyalty, change does not come from the addition of operators, but from the entry of new business models that reduce switching costs, offer radical transparency and create immediate value for the consumer. Some of the possible solutions regarding these threats are diversifying the product offering in an effort to seek other avenues besides the core offerings that form the bulk of their sales, strengthening compliance with antitrust laws, and investing more in research and development in order to come up with more innovative products. Issues of market saturation and similarities with competitors require cooperation with smaller firms and penetration into new regions. In relation to Vodafone Albania and One Albania, such insights show the importance of understanding functional perspectives and using efficient management approaches to maintain a market position and respond to difficulties. By implementing the aforementioned optimization strategies, these firms will be able to mobilize their market positions, encourage innovation, and ensure greater customer satisfaction, which, in turn, will allow them to succeed in the long run.

Future studies should include the use of primary data sources, such as questionnaires, interviews and case studies, in an attempt to determine the actual effects of oligopoly in the mobile phone market. By increasing the range of companies and regions, it will be possible to obtain a broader picture of changes in the industry. Similarly, best practice research conducted in collaboration with other oligopolistic markets may also provide additional and useful perspectives through which the same issues and strategies can be addressed.

5. Conclusions

Given the fact that an oligopolistic market is dominated by Vodafone Albania and One Albania, strategic management and strategic direction are very necessary for market control, innovation revolution, improving the consumer choice front and addressing the legal and labor dilemma.

Thus, the main development strategies identified in relation to the specifics of the market are diversification, compliance with regulations and the ability to increase investments in research and development, transparency, interaction of regulators and new, emerging markets are other key factors that can help solve antitrust problems and market oversaturation. The study analyzed the economic, legal and social effects of the oligopolistic structure in the mobile telephony market in Albania, relying on industrial organization theory, literature review and institutional analysis. Several main conclusions result from the analysis.

First, from an economic perspective, the Albanian mobile telephony market is characterized by a high level of concentration and limited real competition. The behavior of operators is closer to the Cournot model, where competition takes place through similar quantities and packages, than to the Bertrand model, which would produce direct pressure on prices. As a result, prices remain relatively stable and discounts are mainly formal or linked to package structures, without reflecting genuine price competition.

Second, from a legal perspective, the Albanian normative framework for competition and market regulation is formally in line with European Union standards. However, the study highlights a gap between law and practical implementation, where regulatory interventions are often reactive rather than preventive. This limits the ability of regulatory institutions to address oligopolistic behavior and stimulate effective competition.

Third, the social analysis shows that the oligopolistic structure directly affects consumer welfare. High loyalty to existing operators, switching costs, information asymmetry and limited transparency of offers weaken consumer bargaining power and reduce the benefits that would normally flow from a competitive market. Overall, the study concludes that oligopoly in the Albanian mobile telephony market is not just a matter of market structure, but a complex phenomenon with interconnected economic, legal and social implications, requiring coordinated and long-term interventions.

6. Recommendations

Based on the study's conclusions, the recommendations are divided into three main levels: economic, legal-regulatory and social.

Diversification of competition should focus not only on the formal addition of operators, but on the creation of alternative competitive models, such as the inclusion of virtual operators (MVNO).

Price competition should be encouraged by reducing entry barriers and switching costs, creating conditions for the market to move closer to the Bertrand model.

Promoting real innovation in services (network quality, speed, contractual flexibility), as a competitive factor beyond standard packages.

Strengthening the proactive role of the Competition Authority and AKEP, through continuous monitoring of oligopolistic behavior and the prevention of tacit collusion.

Increasing regulatory transparency regarding price structures and standard contracts of operators.

Harmonizing not only formally, but also practically, national policies with the EU acquis communautaire in the field of telecommunications and competition.

Strengthening consumer information mechanisms on their rights and the real price structure.

Simplifying operator switching procedures and reducing hidden costs.

Increasing the role of consumer protection organizations in monitoring commercial practices.

To improve consumer decision-making, organizations need personalization to ensure customer satisfaction and brand loyalty, as the products offered can be customized according to customers' needs and preferences

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MANAGING AQUIFERS & MITIGATING CLIMATE CHANGE: BUILDING THE CASE FOR QUETTA CITY TOWARDS FUTURE SUSTAINABLE WATER MANAGEMENT

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Abstract:

Growing water demands of the world population across the globe are leading to the depletion of ground water resources. Increasing Urbanization is changing the natural recharge patterns of aquifers. High abstraction rates of groundwater are adding more pressure on the already stressed aquifer system of Quetta city in Balochistan province of Pakistan. Pakistan has been declared as the 5th most vulnerable nation to Climate change across the globe with less than 1% contribution to climate change. Depleting water levels are giving rise to water scarcity and land subsidence issues in the Quetta city. For centuries rainwater harvesting and managed aquifer recharge has been practiced in semi-arid and arid areas of the world to conserve water resources. This research evaluated the suitability of MAR implementation to both control and preserve further exploitation of the aquifer. Relevant maps were digitalized to create raster layers of data to develop an understanding of hydrologic and geologic conditions. Estimations reveal that a considerable amount of rainwater can be harvested from different impervious surfaces in the city. Rainwater combined with pre-treated wastewater can reduce the recharge deficit; however the high abstraction rates need to be controlled to achieve a sustainable equilibrium which can last for seeable future.

Keywords: Water Scarcity, Aquifer Recharge, Sustainable Development, Climate Change Challenges, Water Management.

SOME IDENTITIES IN LEFT NEAR-RINGS WITH P-DERIVATIONS**Abdelkarim BOUA**<https://orcid.org/0000-0002-6397-4713>:

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Abstract.

Let N be a near-ring, and let P be a prime ideal of N . In this paper, we introduce the notion of P -derivation in near-rings. Furthermore, we investigate the structure of the quotient near-ring N/P and examine its algebraic properties in relation to generalized- P -derivations.

Key words: 3-prime near-ring; commutativity theorems; derivations; generalized- P -derivations; derivations.

MAHATMA GANDHI AND DR. B.R. AMBEDKAR: CONTESTING VIEWS ON SOCIAL JUSTICE AND DALIT EMANCIPATION

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ABSTRACT

This dissertation examines the contrasting yet deeply intertwined visions of Mahatma Gandhi and Dr. B. R. Ambedkar in their pursuit of social justice and the eradication of untouchability in India. Despite sharing the common goal of liberating the Depressed Classes from centuries of caste-based oppression, the two leaders charted fundamentally different trajectories.

It examines the historical outcome, social indicators and legal reforms. By the different approaches, it enables to draw the core problem and multiple aspects to solve one problem. This emphasised qualitative source to get comprehensive evaluation and root cause of Untouchability.

Here we will look at the issue that is least observed and discuss how to solve it. By focusing more on Caste system and religion, the Economic Exploitation, Ineffective Implementation of Law and Multiple Discrimination against Dalit Women have not been addressed.

This research used Empirical Methodology to examine the contrasting approach of Mahatma Gandhi and Dr. B. R. Ambedkar. It also includes a Comparative Historical Analysis approach like Document Analysis, Contextualisation of sources.

Many studies discuss both leaders' ideas but usually treat them separately not as an ongoing dialogue about social justice. Whereas this study works on political and constitutional issues and least focuses on the Real Dalit experiences which challenge both leaders' views. Subsequently other scholars tried to eradicate the social issue but they still exist.

However, this study aims to fill these gaps by comparing Gandhi's and Ambedkar's writings, letters, speeches and historical documents.

By comparing their writings, speeches, and historical documents, it draws a comprehensive understanding of the root causes of caste-based oppression and untouchability.

A positive outcome of this research is that their combined ideologies contributed significantly to India's legal reforms and constitutional framework for the Depressed Classes. Bridging both leaders' visions through ongoing dialogue and inclusive policymaking remains essential to achieving a truly just and equitable society.

IMPROVING NITROGEN USE EFFICIENCY FOR ENVIRONMENTAL PROTECTION

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Abstract

In agriculture, soil and water pollution by nitrates is significantly exacerbated by the excessive use of nitrogen fertilizers, which can lead to major environmental impacts such as eutrophication, groundwater contamination, and health risks.

Several strategies have been developed to address these issues by reducing nitrogen inputs while improving nitrogen use efficiency and maintaining agricultural productivity.

These strategies include adjusting fertilizer application rates, using slow-release fertilizers, applying precision fertilization tailored to crop needs, introducing nitrogen-fixing crops such as legumes, practicing crop rotation, and improving agricultural techniques.

These approaches not only help limit nitrogen losses to the environment but also enhance the quality of agricultural products and reduce costs for farmers. They form part of a broader effort to ensure the sustainability of agricultural systems in the face of climate change, balancing productivity, environmental protection, and resilience.

Keywords

Nitrate pollution, Nitrogen fertilizers, Groundwater contamination, Eutrophication, Precision fertilization, Sustainable agricultura, Environmental protection, Climate change resilience

AI GOVERNANCE FRAMEWORKS FOR DIGITAL TRANSFORMATION

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Abstract

Digital transformation presents new governance challenges, especially with AI deployment in organizations. This research develops a comprehensive AI governance framework, integrating risk assessment, compliance, and ethical considerations. Using qualitative interviews with CIOs and AI practitioners across sectors, combined with literature analysis, the study identifies key governance dimensions, accountability, transparency, and stakeholder engagement. The framework is validated against case studies in healthcare and finance, demonstrating improved AI adoption outcomes, reduced regulatory risks, and enhanced organizational trust. This research contributes to best practices for aligning AI initiatives with strategic digital transformation objectives while mitigating operational, ethical, and reputational risks.

Keywords: governance, considerations, qualitative, governance dimensions.

HARNESSING SAHARAN ACTINOMYCETES FOR INNOVATIVE AND SUSTAINABLE PHYTOPATHOGEN CONTROL

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Abstract:

The search for alternative strategies to combat plant diseases has intensified due to the environmental and health concerns associated with chemical fungicides. Saharan soils, particularly those of Tamanrasset, offer a unique ecological niche for discovering microorganisms with enhanced biotechnological potential. This study isolated forty actinomycete strains using selective heat treatment and calcium carbonate enrichment techniques.

Characterization of the isolates revealed strong ecological adaptability and metabolic diversity. These traits are essential for survival in extreme desert environments and are often linked to the production of bioactive secondary metabolites. In vitro antagonism assays demonstrated significant suppression of major phytopathogens, especially *Fusarium* and *Alternaria*, with inhibition zones reaching 40 mm in some cases.

The superior antagonistic activity observed may result from evolutionary adaptation to competitive and resource-limited ecosystems. The exploitation of these desert-derived actinomycetes represents a promising and sustainable approach to crop protection. Their integration into agricultural practices could reduce chemical inputs while maintaining effective disease control, thereby supporting global efforts toward greener and more resilient farming systems.

Keywords: Saharan biodiversity; Biopesticides; Microbial diversity; Desert soils; Crop protection

ADAPTATION-DRIVEN ANTIFUNGAL ACTIVITY OF ACTINOBACTERIA FROM TAMANRASSET DESERT SOILS

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Abstract:

Extreme environments such as the Saharan desert impose strong selective pressures that shape microbial evolution and metabolic specialization. This study examines actinobacterial strains isolated from Tamanrasset's arid soils and assesses their potential for biological control of fungal plant pathogens. Selective isolation was achieved through heat pretreatment and mineral enrichment, yielding forty distinct strains.

The physiological robustness of these isolates reflects their adaptation to harsh desert conditions. Such resilience is closely linked to their ability to synthesize diverse and stable secondary metabolites. Antifungal screening revealed pronounced antagonistic interactions against *Alternaria* and *Fusarium* species, with certain isolates producing large inhibition zones indicative of high bioactivity.

The data support the hypothesis that environmental stress enhances the development of competitive survival strategies, including antimicrobial compound production. These findings underscore the value of exploring extreme habitats for innovative biocontrol agents. The integration of Saharan actinobacteria into agricultural systems could reduce dependency on chemical pesticides and promote environmentally sustainable crop protection solutions.

Keywords: Actinobacteria; Desert adaptation; Antifungal metabolites; Tamanrasset; Biological control

SAHARAN MICROBIAL RESOURCES AS A SUSTAINABLE STRATEGY FOR CROP DISEASE MANAGEMENT

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Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

Abstract:

Arid ecosystems are increasingly recognized as valuable sources of novel microorganisms with unique metabolic capabilities. This investigation explores the microbial diversity of Tamanrasset's desert soils and its relevance for phytopathogen suppression. Using selective isolation techniques involving thermal treatment and CaCO₃ enrichment, forty actinomycete isolates were recovered and evaluated for their antagonistic properties.

The isolates displayed strong ecological resilience, reflecting their adaptation to high temperatures, limited water availability, and poor nutrient conditions. These environmental constraints likely stimulate the biosynthesis of potent secondary metabolites that enhance microbial competitiveness. Antagonistic screening assays revealed significant inhibitory effects against fungal pathogens responsible for severe crop losses. Notably, some strains exhibited inhibition zones up to 40 mm against *Fusarium* and *Alternaria*, demonstrating high antifungal efficacy.

The results suggest that Saharan actinomycetes possess efficient biochemical defense mechanisms that can be harnessed for agricultural applications. Their bioactive metabolites offer promising alternatives to synthetic fungicides, reducing environmental contamination and minimizing resistance development in pathogens. By valorizing desert microbial biodiversity, this research contributes to the advancement of eco-friendly plant disease management strategies and supports sustainable agricultural development.

Keywords: Desert microbiology; Phytopathogens; Antagonistic activity; Natural metabolites; Eco-friendly control

BIOCONTROL POTENTIAL OF SAHARAN ACTINOMYCETES ISOLATED FROM TAMANRASSET ARID SOILS

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Abstract:

The hyper-arid soils of Tamanrasset in southern Algeria constitute an underexplored reservoir of microbial diversity with promising agricultural applications. This study focuses on the isolation and characterization of actinomycete strains adapted to extreme Saharan conditions and evaluates their potential as biological control agents against major phytopathogenic fungi. Soil samples were subjected to heat pretreatment and calcium carbonate enrichment to selectively isolate spore-forming actinobacteria. A total of forty morphologically distinct strains were obtained and screened for antagonistic activity.

Physiological characterization revealed that these isolates are highly adapted to harsh environmental stresses, including desiccation and nutrient limitation. Such adaptations appear to be associated with the production of stable and bioactive secondary metabolites. In vitro antagonism assays demonstrated strong inhibitory effects against economically important phytopathogens, particularly *Alternaria* and *Fusarium* species. Several isolates produced inhibition zones reaching up to 40 mm, indicating significant antifungal activity.

The remarkable antagonistic performance of these strains may reflect evolutionary pressures imposed by the extreme Saharan ecosystem, where microbial competition for limited resources is intense. These findings highlight the potential of Saharan actinomycetes as sustainable alternatives to chemical fungicides. Their exploitation could contribute to environmentally friendly crop protection strategies and support the development of integrated pest management systems in modern agriculture.

Keywords: Saharan actinomycetes; Biological control; Tamanrasset soils; Antifungal activity; Sustainable agriculture

RELATIONSHIP BETWEEN FOOT PAIN AND DIFFERENT SHOE BASE AREA

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Abstract

Foot pain represents a prevalent musculoskeletal complaint frequently associated with altered plantar loading patterns influenced by footwear geometry, particularly shoe base width. The base width, commonly quantified as the plantar contact area between the foot sole and the ground (cm²), plays a decisive role in mechanical load transfer during standing and gait. Reduction in contact area concentrates the same vertical body weight over a smaller surface, leading to substantial elevations in peak plantar pressure. Experimental pressure-mapping studies demonstrate that narrow-base footwear (rearfoot contact area approximately 20–30 cm²) can generate peak pressures ranging from 450 to 600 kPa, whereas wider-base designs (45–60 cm²) typically restrict pressures to 250–350 kPa, reflecting increases of up to 70% under identical loading conditions. This mechanical concentration promotes localized stress beneath the metatarsal heads and hallux, regions frequently associated with pain syndromes. Narrow bases are also linked to increased centre-of-pressure excursion and longer postural sway paths, indicating diminished stability and greater neuromuscular demand. Electromyographic findings further reveal elevated activation of stabilizing muscles during standing in narrow-base shoes, accelerating fatigue development. Collectively, these biomechanical alterations provide a mechanistic explanation for the higher incidence of discomfort observed with reduced shoe base width. Adequate plantar contact area should therefore be prioritized in footwear design to optimize load distribution, enhance stability, and reduce foot pain risk.

Keywords: Foot pain; Shoe base width; Postural stability; Load distribution

DIGITAL FORENSICS IN CYBERCRIME INVESTIGATION

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1. Abstract

The rapid growth of digital technologies and internet usage has led to a significant increase in cybercrimes such as hacking, identity theft, financial fraud, and data breaches. Investigating these crimes requires specialized techniques to identify, collect, analyze, and preserve digital evidence. Digital forensics has emerged as a critical discipline in cybercrime investigation, enabling investigators to uncover hidden data and reconstruct digital events.

Digital forensics involves the systematic examination of electronic devices including computers, mobile phones, networks, and cloud systems. By using advanced forensic tools and methodologies, investigators can retrieve deleted files, track malicious activities, and identify cybercriminals while ensuring the integrity of digital evidence.

This paper presents an analytical study of digital forensics in cybercrime investigation, focusing on its methodologies, tools, and applications. It also discusses key challenges such as data privacy, encryption, large-scale data analysis, and legal constraints. The study highlights the importance of digital forensics in strengthening cybersecurity and supporting law enforcement agencies in combating cybercrime effectively.

2. Keywords

Digital Forensics, Cybercrime Investigation, Computer Forensics, Network Forensics, Mobile Forensics, Digital Evidence, Cybersecurity

3. Introduction

The rapid expansion of digital technologies has transformed modern society by enabling faster communication, online transactions, and global connectivity. However, this technological advancement has also led to a rise in cybercrimes that threaten individuals, organizations, and governments. Cybercriminals exploit vulnerabilities in computer systems and networks to steal sensitive data, disrupt services, and commit financial fraud.

Traditional investigation methods are often insufficient to handle cybercrime cases because digital evidence can be easily altered, deleted, or hidden. Digital forensics has therefore become an essential field in modern cybercrime investigations. It involves the identification,

preservation, analysis, and presentation of digital evidence obtained from electronic devices and network systems.

Digital forensic techniques allow investigators to recover deleted data, analyze system logs, trace cyberattack origins, and understand the behavior of malicious software. These techniques are widely used in law enforcement, corporate investigations, and cybersecurity incident response.

This paper explores the role of digital forensics in cybercrime investigation by analyzing its methodologies, tools, and practical challenges. The study aims to highlight how digital forensic technologies help in identifying cybercriminals and ensuring the integrity of digital evidence in legal proceedings.

4. Related Work

Researchers have conducted extensive studies on digital forensics to improve the effectiveness of cybercrime investigations. Early forensic investigations focused primarily on computer forensics, which involved analyzing hard drives and storage devices to retrieve digital evidence. Over time, the scope of digital forensics expanded to include mobile devices, network traffic, and cloud environments.

Several research studies have proposed advanced forensic techniques for recovering deleted data, detecting malware activities, and analyzing network intrusions. Tools such as EnCase, FTK, and Autopsy have been widely used for forensic analysis. In addition, network forensics techniques have been developed to monitor suspicious activities and detect cyberattacks in real time.

Recent research has also explored the integration of artificial intelligence and machine learning in digital forensics to automate evidence analysis and improve investigation efficiency. However, challenges such as encrypted data, large-scale data volumes, and legal restrictions still affect the effectiveness of digital forensic investigations.

These studies indicate that digital forensics plays a crucial role in cybercrime investigation, but continuous advancements are required to address emerging cyber threats and evolving digital environments.

5. Proposed Methodology

The digital forensic investigation process follows a structured methodology designed to ensure the accuracy and integrity of digital evidence.

The first stage involves the identification of digital evidence, where investigators determine the devices, systems, and storage media that may contain relevant information. This includes computers, mobile phones, servers, and network devices.

The second stage is evidence collection and preservation, where digital data is carefully acquired using forensic tools while maintaining the integrity of the original data. Techniques such as disk imaging and hash verification are used to ensure that evidence remains unchanged.

The third stage involves analysis of digital evidence. Investigators examine files, system logs, browsing history, and network traffic to identify suspicious activities and reconstruct the sequence of events related to the cybercrime.

The final stage is documentation and presentation, where investigators prepare detailed reports and present their findings as evidence in legal proceedings. This structured methodology ensures reliability, accuracy, and admissibility of digital evidence.

6. Advantages

Digital forensics provides several important benefits in cybercrime investigations:

Accurate Evidence Collection: Enables the retrieval and preservation of reliable digital evidence.

Crime Reconstruction: Helps investigators understand how cyberattacks occurred.

Data Recovery: Allows recovery of deleted or hidden files.

Legal Support: Provides credible evidence that can be presented in court.

Cybersecurity Improvement: Helps organizations identify vulnerabilities and strengthen security systems.

7. Challenges and Limitations

Despite its importance, digital forensics faces several challenges:

Data Volume: Large amounts of digital data make investigation time-consuming.

Encryption Technologies: Encrypted data can limit evidence access.

Rapid Technological Changes: New devices and technologies require updated forensic tools.

Legal and Privacy Issues: Handling personal data during investigations raises legal concerns.

Cloud Computing Challenges: Investigating data stored in distributed cloud systems is complex.

Addressing these challenges is necessary to improve the efficiency and reliability of digital forensic investigations.

8. Conclusion

Digital forensics has become an essential component of modern cybercrime investigation. It enables investigators to collect, analyze, and preserve digital evidence from various electronic devices and networks. Through systematic forensic methodologies and advanced tools, digital forensics helps uncover cybercriminal activities and supports law enforcement agencies in solving complex cybercrime cases.

However, challenges such as encryption, large-scale data analysis, and legal regulations must be addressed to enhance the effectiveness of digital forensic investigations. Future research should focus on developing advanced forensic technologies, integrating artificial intelligence for automated analysis, and establishing standardized legal frameworks. With continuous advancements, digital forensics will play a crucial role in strengthening cybersecurity and combating cybercrime in the digital era.

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INTEGRATING CASE STUDIES IN ENGLISH LANGUAGE TEACHING: DEVELOPING INTERCULTURAL COMPETENCE IN HIGHER EDUCATION

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ABSTRACT

In the context of globalization and the increasing internationalization of higher education, the development of intercultural competence has become an essential objective in English language education. This study explores the effectiveness of the case study technique as a pedagogical approach for fostering intercultural competence among university students studying English as a foreign language. The research was conducted with undergraduate students enrolled in the English Language program at “Aleksandër Moisiu” University in Durrës.

The study employed a classroom-based instructional intervention in which students analyzed intercultural scenarios through the case study technique. Students worked collaboratively in small groups to examine cultural misunderstandings, discuss possible interpretations, and propose appropriate responses. Classroom observations, group discussions, and students’ reflections were used to evaluate the learning outcomes of the activity.

The findings indicate that the case study technique significantly enhanced students’ intercultural awareness and encouraged them to reflect critically on cultural differences. In addition, the activity promoted the development of critical thinking, collaborative learning, and oral expression in English. Students reported that analyzing realistic intercultural situations helped them better understand cultural perspectives and increased their sensitivity toward cultural diversity.

The results suggest that integrating case studies into English language teaching can provide meaningful opportunities for students to connect language learning with real-life intercultural contexts. By combining linguistic practice with cultural analysis, the case study technique offers an effective pedagogical strategy for supporting the development of intercultural competence in higher education.

Keywords: intercultural competence, case study technique, English language teaching, higher education, intercultural learning.

INTRODUCTION

In the contemporary context of globalization and the internationalization of higher education, the ability to communicate effectively across cultures has become an essential component of

language education. English, as a global lingua franca, is widely used in multicultural academic, professional, and social environments. Consequently, the teaching of English in higher education institutions increasingly emphasizes not only the development of linguistic competence but also the cultivation of intercultural awareness and the ability to interact effectively with individuals from diverse cultural backgrounds (Kramsch, 1993). For this reason, the development of intercultural competence has become a central objective in foreign language education.

Intercultural competence refers to the ability to understand, interpret, and interact appropriately with people from different cultural contexts. According to Byram (1997), successful communication in a foreign language requires not only grammatical and linguistic knowledge but also cultural awareness, attitudes of openness, and the ability to interpret and relate cultural differences. In a similar vein, Deardorff (2006) conceptualizes intercultural competence as a dynamic process that integrates attitudes, knowledge, skills, and internal outcomes such as adaptability and empathy that enable individuals to communicate effectively and appropriately in intercultural situations. These perspectives highlight the importance of integrating cultural dimensions into language teaching practices.

In recent years, educators and researchers have increasingly explored innovative teaching techniques that support the development of intercultural competence in language classrooms. Traditional approaches that focus primarily on grammar and vocabulary are often insufficient for preparing students to engage in real intercultural competence. Instead, scholars suggest that language education should incorporate experiential and interactive learning strategies that encourage students to reflect on cultural differences and develop critical perspectives toward intercultural interactions (Bennett, 1993; Risager, 2007).

Among the various pedagogical techniques proposed in the literature, the case study technique has gained increasing attention in higher education. The case study approach involves presenting learners with realistic or hypothetical situations that require analysis, interpretation, and decision-making. These scenarios often include cultural misunderstandings, communication breakdowns, or ethical dilemmas that arise from differences in cultural norms and expectations. Through discussion and collaborative analysis, students are encouraged to examine multiple cultural perspectives and propose possible solutions (Herreid, 2007).

In the context of English language teaching, case studies represent an effective pedagogical tool for connecting linguistic practice with authentic intercultural situations. By engaging with real-life scenarios, students can develop not only language proficiency but also the analytical and

reflective skills necessary for understanding cultural diversity. Such activities encourage students to interpret cultural behaviors, question stereotypes, and develop empathy toward other cultures (Sercu, 2005).

Within this framework, the present study explores the use of the case study technique as a pedagogical approach for fostering intercultural competence among students of English language studies in higher education. The study focuses on students enrolled in the English Language program at Aleksandër Moisiu University in Durrës. By examining students' engagement with intercultural case scenarios and their reflections on the learning process, this research aims to evaluate how the case study technique can support the development of intercultural awareness and communicative skills in English language classrooms.

RESEARCH AND FINDINGS

This section presents the research design, the implementation of the case study technique in the classroom, and the main findings related to students' perceptions and learning outcomes. The purpose of this section is to illustrate how the case study technique can function as a practical teaching strategy for developing intercultural competence among students of English language studies in higher education.

The study was conducted at Aleksandër Moisiu University in Durrës (UAMD), within the Bachelor program in English Language. Students enrolled in this program are exposed to courses related to language skills, literature, culture, and English language teaching methodology. In such an academic context, the development of intercultural competence represents an important component of students' academic and professional preparation, particularly for those who may pursue careers in teaching, translation, or international communication.

The study involved a group of 34 undergraduate students enrolled in the English Language Bachelor program at Aleksandër Moisiu University in Durrës. All participants had an intermediate to advanced level of English proficiency (approximately B2–C1 according to the Common European Framework of Reference for Languages). The activity was implemented during regular classroom sessions and formed part of a course that integrates language learning with cultural and communicative analysis. Participation in the activity was voluntary, and students were informed that the purpose of the task was to explore intercultural competence through collaborative discussion and reflection.

Data for the study were collected through classroom observation, group discussions, and students' reflective comments following the case study activities. The collected qualitative data

were analyzed using a thematic analysis approach, focusing on recurring themes related to intercultural awareness, communication strategies, and students' perceptions of the learning process. The analysis aimed to identify how students interpreted intercultural situations and how the case study activities contributed to the development of critical thinking, cultural sensitivity, and communicative competence in English.

The instructional intervention was implemented over two classroom sessions in which students worked with intercultural case scenarios designed to stimulate discussion and reflection. Each case described a situation involving cultural misunderstandings in academic or professional contexts. Students were asked to analyze the situations in small groups and respond to guiding questions related to communication styles, cultural expectations, and appropriate responses in intercultural interactions. The lecturer facilitated the discussions and encouraged students to justify their interpretations and consider alternative cultural perspectives.

Teaching Intervention: Implementation of the Case Study Technique

The research focused on the use of the case study technique as an instructional activity integrated into regular classroom teaching. Case studies were selected because they present students with authentic or simulated situations that require interpretation, discussion, and decision-making. This technique encourages students to analyze cultural differences and reflect on how cultural norms influence communication (Herreid, 2007).

During the teaching intervention, students were introduced to several intercultural scenarios that represented realistic situations in which communication difficulties might occur due to cultural differences. Each case study was designed to provoke discussion and critical analysis rather than to provide a single correct answer.

The activity followed a structured learning process consisting of several stages.

Stage 1 – Presentation of the Case

The lecturer presented a short-written scenario describing an intercultural situation. Students were given time to read the case individually and identify the main issue presented in the scenario. At this stage, students were encouraged to consider what cultural factors might influence the interaction described in the case.

Stage 2 – Group Analysis

Students were divided into small groups of three to four members. Each group analyzed the case and discussed several guiding questions prepared by the lecturer. These questions aimed to help students identify the cultural misunderstandings present in the situation and consider possible interpretations.

Typical guiding questions included:

- What is the main problem in this situation?
- Which cultural differences may explain the misunderstanding?
- How might people from different cultural backgrounds interpret this situation differently?
- What would be the most appropriate response in this context?

Stage 3 – Presentation and Discussion

After the group discussion, each group presented its interpretation of the case to the rest of the class. Students explained their reasoning and proposed possible solutions to the communication problem. This stage generated extensive classroom discussion, as students compared different interpretations and perspectives.

Stage 4 – Reflection

Finally, the lecturer facilitated a reflective discussion in which students evaluated the cultural assumptions present in the case. Students were encouraged to reflect on how their own cultural perspectives influenced their interpretation of the situation.

Example of an Intercultural Case Study Used in the Classroom

One of the case studies used during the activity described a situation involving an international student and a university lecturer.

Case scenario

An international student studying in a foreign university sends an email to a professor addressing the professor by their first name and requesting an extension for an assignment. The message is written in a very direct style. The professor perceives the message as disrespectful and responds negatively.

Students were asked to analyze the situation and discuss the following issues:

- whether the student intended to be disrespectful
- how forms of politeness differ across cultures
- how academic communication norms vary in different countries
- what would be a culturally appropriate way to communicate with a professor.

This case generated a variety of interpretations among students. Some students emphasized that in many cultures addressing teachers by their first name is considered acceptable, while others noted that in more formal academic environments this behavior may be perceived as inappropriate. Through discussion, students became aware of how communication norms vary across cultures.

Classroom observations indicated a high level of student engagement during the case study activities. Students participated actively in group discussions and demonstrated interest in exploring different cultural perspectives. Many students expressed that analyzing real-life communication situations helped them understand how cultural differences influence interaction.

Students particularly appreciated the collaborative aspect of the activity. Working in groups allowed them to exchange ideas and compare their interpretations with those of their peers. This process contributed to a deeper understanding of the cultural dimensions involved in communication.

Following the activity, students were asked to reflect on their experience with the case study technique. Their responses indicated several perceived benefits of this teaching technique.

First, students reported that the case studies helped them understand how cultural differences influence communication. Instead of learning cultural information in an abstract way, they were able to analyze specific situations that illustrated real communication challenges.

Second, students noted that the activity improved their speaking and discussion skills in English. Because the cases required interpretation and argumentation, students were encouraged to express their opinions and justify their ideas using English.

Third, many students highlighted that the activity increased their awareness of the importance of cultural sensitivity in communication. Through discussion, students realized that behaviors that appear normal in one culture may be interpreted differently in another.

These findings support the idea that experiential learning activities such as case studies can facilitate the development of intercultural competence by encouraging students to analyze cultural perspectives and reflect on their own assumptions.

One of the most important outcomes of the activity was the development of students' intercultural awareness. Through the analysis of different scenarios, students began to recognize the complexity of intercultural competence and the role that cultural values and norms play in shaping interaction.

Students demonstrated increased sensitivity toward cultural differences and a greater willingness to consider alternative perspectives. This aligns with the view that intercultural competence develops through reflective engagement with cultural diversity and through opportunities to analyze authentic intercultural situations (Byram, 1997; Deardorff, 2006).

Overall, the findings of the study suggest that the case study technique can serve as an effective pedagogical tool in English language teaching. By combining language practice with the

analysis of intercultural situations, case studies create opportunities for students to develop both communicative and intercultural skills within a meaningful educational context.

In addition to increasing students' intercultural awareness, the case study activities also contributed to the development of several important academic and communicative skills. Classroom observations and student reflections indicated that the use of case studies encouraged active participation and collaborative learning. Students were required not only to understand the situation presented in the case but also to analyze the perspectives of different cultural actors and justify their interpretations during group discussions.

One of the most noticeable outcomes was the improvement of students' analytical thinking. The case scenarios required students to identify the underlying causes of intercultural misunderstandings and to consider multiple interpretations of the same situation. This process helped students move beyond simple cultural stereotypes and develop a more nuanced understanding of cultural diversity.

Furthermore, the case study activities created opportunities for students to practice argumentative communication in English. During group discussions and presentations, students were encouraged to express their opinions, support their arguments with explanations, and respond to alternative viewpoints presented by their classmates. Such interactions not only strengthened their speaking skills but also promoted critical reflection on cultural assumptions. Another important outcome was the development of empathy toward different cultural perspectives. When analyzing intercultural situations, students were encouraged to consider how individuals from different cultural backgrounds might interpret the same interaction differently. This process helped students recognize the importance of tolerance, flexibility, and openness in intercultural communication.

Despite the positive outcomes, several challenges were also observed during the implementation of the case study technique. One of the main challenges was the time required for meaningful discussion. Case study activities often generate extensive classroom dialogue, which can limit the number of cases that can be analyzed within a single session.

Another challenge involved students' initial uncertainty when interpreting complex intercultural situations. Some students initially expected clear or definitive answers to the cases presented. However, as the activity progressed, they gradually understood that intercultural competence often involves multiple perspectives and that different interpretations can coexist.

In addition, the effectiveness of case studies depends greatly on the lecturer's ability to facilitate discussion and guide students toward deeper reflection. Without careful moderation, discussions may remain superficial and fail to explore the cultural dimensions of the scenario. The findings of this study are consistent with previous research on the role of experiential learning in developing intercultural competence. Scholars have emphasized that activities which involve analysis of real-life situations can significantly enhance students' ability to understand cultural differences and engage in meaningful intercultural communication (Byram, 1997; Deardorff, 2006). Similarly, research on case-based learning suggests that the technique promotes critical thinking, collaborative learning, and problem-solving skills in higher education contexts (Herreid, 2007).

In the context of English language teaching, integrating case studies into classroom practice allows students to combine linguistic practice with cultural analysis. Such activities help bridge the gap between theoretical knowledge of culture and practical intercultural skills. As a result, students become better prepared to navigate multicultural academic and professional environments.

Interpretation of the Results

The analysis of the classroom activities and students' reflections revealed several important findings regarding the effectiveness of the case study technique in developing intercultural competence among students of the English Language program. The findings demonstrate that the integration of case studies in English language teaching can enhance students' intercultural awareness, promote critical thinking, and encourage active participation in classroom discussions.

One of the most significant findings of the study was the noticeable increase in students' awareness of cultural differences and their impact on communication. Through the analysis of intercultural scenarios, students were exposed to situations in which misunderstandings occurred due to different cultural norms, expectations, and communication styles. Many students initially interpreted these situations based on their own cultural perspectives; however, through group discussion and reflection, they began to recognize that behaviors may be interpreted differently across cultures.

Students demonstrated an increasing ability to identify cultural factors that influence communication, such as forms of politeness, attitudes toward hierarchy, communication styles, and expectations in academic or professional contexts. By examining these elements, students developed a deeper understanding of how cultural background shapes interaction and

interpretation. This finding supports the idea that intercultural competence develops through reflective engagement with cultural diversity and through opportunities to analyze authentic intercultural situations.

Another important finding was the role of case studies in promoting critical thinking among students. Unlike traditional teaching methods that often focus on memorization of cultural information, the case study approach required students to analyze complex situations and consider multiple perspectives. Students were asked to interpret the motivations of the individuals involved in the scenario, evaluate possible explanations for the misunderstanding, and propose appropriate solutions.

During group discussions, students frequently debated different interpretations of the same case. This process encouraged them to question initial assumptions and consider alternative explanations based on cultural context. As a result, students developed stronger analytical skills and a more reflective approach to intercultural competence.

The use of case studies also contributed to the development of students' oral communication skills in English. Because the activities required students to explain their interpretations and justify their ideas during group discussions and presentations, students were actively engaged in speaking and argumentative interaction.

Students demonstrated increased confidence in expressing their opinions in English and participating in classroom discussions. In many cases, students expanded their responses by providing examples from their own experiences or by comparing cultural practices in different countries. This type of interaction created a dynamic learning environment in which language use was connected to meaningful cultural analysis.

Another important finding was the positive impact of the case study technique on collaborative learning. The group-based nature of the activity encouraged students to share their perspectives and negotiate meaning collectively. Through discussion with their peers, students were exposed to different viewpoints and interpretations of the same cultural situation.

Classroom observations indicated that students were highly engaged during the activity. The realistic nature of the case scenarios stimulated curiosity and encouraged students to explore possible explanations for the situations presented. Students appeared motivated to participate in discussions and showed interest in understanding the cultural aspects of communication.

Students' reflective comments further confirmed the effectiveness of the case study technique as a learning tool. Many students reported that analyzing real-life intercultural situations helped them better understand how cultural differences influence communication. Instead of learning

cultural concepts in a theoretical manner, students were able to apply their knowledge to practical scenarios.

Several students noted that the activity helped them become more aware of the importance of cultural sensitivity when communicating in English. They also expressed that the discussions allowed them to recognize that misunderstandings in intercultural matters are often the result of different expectations rather than intentional disrespect.

Overall, the findings suggest that the use of case studies can significantly contribute to the development of intercultural competence in English language classrooms. The technique creates opportunities for students to analyze authentic communication situations, reflect on cultural differences, and develop the skills necessary for effective intercultural interaction. By combining language practice with critical cultural analysis, case studies offer a valuable pedagogical approach for preparing students to communicate in diverse global contexts.

These results indicate that integrating case studies into English language teaching in higher education can provide meaningful learning experiences that support both linguistic and intercultural development.

The classroom observations indicated that the majority of students actively participated in the discussions, demonstrating increased awareness of intercultural issues and a willingness to consider multiple cultural perspectives.

CONCLUSION

The present study examined the role of the case study technique in fostering intercultural competence among students enrolled in the English Language program in higher education. In the context of increasing globalization and international academic interaction, the ability to communicate effectively across cultures has become an essential component of language education. Consequently, English language teaching in universities must go beyond the development of linguistic proficiency and incorporate pedagogical approaches that encourage students to understand and navigate cultural diversity.

The findings of the study indicate that the case study technique can serve as an effective instructional strategy for developing students' intercultural competence. Through the analysis of intercultural scenarios, students were able to explore cultural differences, reflect on communication norms, and examine how cultural perspectives influence interpretation and behavior. The discussions generated during the case study activities created opportunities for students to analyze real-life situations and consider multiple viewpoints, which contributed to the development of intercultural awareness.

In addition to enhancing intercultural understanding, the case study technique also supported the development of several important academic skills. Students demonstrated improved critical thinking as they evaluated different explanations for intercultural misunderstandings and proposed possible solutions. Furthermore, the activity encouraged active participation and collaborative learning, allowing students to exchange ideas and compare cultural perspectives within group discussions. These interactions also contributed to the improvement of students' oral communication skills in English, as they were required to explain their reasoning and justify their interpretations.

Another important outcome of the study was the increased awareness among students regarding the complexity of intercultural communication. Through reflection and discussion, students recognized that behaviors perceived as appropriate in one cultural context may be interpreted differently in another. This realization helped students develop a more flexible and open-minded attitude toward cultural diversity, which is a key component of intercultural competence.

Despite the positive outcomes observed in this study, several considerations should be noted. The implementation of case studies requires careful planning and effective facilitation by the lecturer in order to ensure meaningful discussion and reflection. Additionally, sufficient classroom time must be allocated to allow students to analyze the cases thoroughly and explore the cultural dimensions involved in each situation. Future studies may further explore the integration of case studies with other teaching techniques such as debates, simulations, or multimedia materials in order to enhance intercultural learning experiences.

Overall, the results of this study suggest that the integration of case studies into English language teaching in higher education can provide valuable opportunities for students to develop intercultural awareness and communicative competence. By engaging students in the analysis of authentic intercultural situations, the case study technique helps bridge the gap between theoretical knowledge of culture and practical communication skills. As higher education institutions continue to promote internationalization and intercultural dialogue, teaching approaches that combine language learning with cultural analysis will play an increasingly important role in preparing students for participation in a globalized world.

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ON PAIRED KANNAN-TYPE CONTRACTIONS VIA PAIRED CONTRACTIONS IN PARTIAL METRIC SPACES

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Abstract:

Fixed point theory plays a pivotal role in nonlinear analysis and has undergone extensive development through generalizations of contractive conditions and the structures of underlying spaces. In metric spaces, Banach's contraction principle and its variations, including Kannan and paired contractions, have been extensively studied; nevertheless, the concept of paired contraction has not yet been fully explored in the context of partial metric spaces. In this paper, a novel class of contractive map pings, called paired Kannan-type contractions, is introduced for both single-valued and multivalued mappings in complete partial metric spaces. Comparative examples are given to support the assumptions and show how the theoretical findings are applied.

Keywords and Phrases: fixed point; paired contraction; partial Hausdorff metric

2010 Mathematics Subject Classification : 47H10; 54H25.

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REAL-TIME FAULT MONITORING BY SENSOR-BASED MACHINE LEARNING (ML) WITH ELECTROMAGNETIC (EM) FIELD ENERGY HARVESTING

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ABSTRACT

An innovative, sustainable solution for real-time fault monitoring in electrical distribution conductors by combining sensor-based machine learning (ML) with electromagnetic (EM) field energy harvesting. The system utilizes strategically deployed, low-power sensors that capture electrical and environmental parameters from conductors. These data streams are analyzed by ML models capable of detecting incipient and developing faults with high accuracy. To eliminate reliance on external power supplies and reduce maintenance, each sensor node autonomously harvests operational energy from the surrounding EM field, supporting uninterrupted monitoring. Laboratory and field validations confirm that this approach significantly enhances fault detection precision, extends monitoring coverage, and minimizes operational costs. The proposed methodology paves the way for resilient, intelligent, and eco-friendly distribution network management.

Keywords: Sensor-based machine learning (ML), Electromagnetic (EM) field energy harvesting, Fault detection precision, Machine learning, eco-friendly distribution network management.

ADVANCED PHARMACOLOGICAL PERSPECTIVES ON ANTIARRHYTHMIC DRUG THERAPY: ION CHANNEL MODULATION, PHARMACOKINETIC VARIABILITY, METABOLIC REGULATION, THERAPEUTIC MONITORING, AND CLINICAL SAFETY CONSIDERATIONS

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Abstract

Cardiac arrhythmias represent a heterogeneous group of disorders characterized by abnormalities in the generation or conduction of electrical impulses within the heart. These disturbances may result in tachycardia, bradycardia, or irregular cardiac rhythms and can lead to significant morbidity and mortality if not appropriately managed. Antiarrhythmic medications remain one of the fundamental therapeutic strategies used in clinical cardiology for the prevention, control, and treatment of rhythm disturbances. The pharmacological effectiveness and safety of these agents largely depend on their pharmacodynamic and pharmacokinetic properties, which determine their mechanisms of action, distribution within tissues, metabolic pathways, elimination processes, and potential interactions with other drugs.

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A detailed understanding of these characteristics is essential for optimizing therapeutic outcomes and minimizing adverse effects associated with antiarrhythmic therapy. The aim of the present study was to analyze and summarize the peculiarities of pharmacodynamics and pharmacokinetics of several important antiarrhythmic medicines commonly used in clinical practice. Special attention was devoted to the mechanisms of action, metabolic pathways, elimination characteristics, and clinical implications of these pharmacological agents. The work also sought to evaluate the influence of physiological conditions, enzymatic activity, and potential drug–drug interactions on the pharmacological behavior of these medications. The methodological framework of the research was based on a comprehensive review and systematic analysis of contemporary scientific literature. Relevant publications were identified through extensive searches in internationally recognized databases including PubMed, Web of Science, ClinicalKey, Thomson Reuter’s databases, Google Scholar, the Cochrane Library, and Elsevier scientific repositories. National and international clinical guidelines, pharmacological reviews, and other grey literature sources were also examined to ensure a broad and critical evaluation of the available evidence. The collected data were processed using analytical, comparative, and generalization approaches in order to identify key pharmacological features and clinical considerations related to antiarrhythmic drug therapy. The analysis demonstrated that antiarrhythmic drugs exert their therapeutic effects primarily through modulation of cardiac ion channels responsible for the generation and propagation of electrical impulses in myocardial cells. Sodium, potassium, and calcium channels play fundamental roles in determining the electrophysiological behavior of cardiomyocytes, and many antiarrhythmic agents act by selectively blocking or modulating these channels. Such interactions influence action potential duration, refractory periods, and conduction velocity within cardiac tissue. Among the agents evaluated, quinidine, amiodarone, and sotalol exhibit distinctive pharmacodynamic profiles. Quinidine primarily acts as a sodium channel blocker that slows cardiac conduction and prolongs the action potential duration, thereby stabilizing abnormal rhythms. Amiodarone demonstrates a complex pharmacodynamic spectrum by affecting multiple ion channels and adrenergic receptors, which contributes to its high efficacy in treating various supraventricular and ventricular arrhythmias. Sotalol combines class III antiarrhythmic activity with non-selective beta-adrenergic blocking properties, prolonging myocardial repolarization and refractory periods. Pharmacokinetic analysis reveals significant differences among these medications in terms of absorption, distribution, metabolism, and elimination. Quinidine is rapidly absorbed after oral administration but undergoes substantial first-pass hepatic

metabolism, which reduces its systemic bioavailability. Amiodarone displays highly variable absorption and extensive distribution into tissues due to its pronounced lipophilicity, leading to accumulation in organs such as the liver, lungs, and adipose tissue. One of the most distinctive features of amiodarone pharmacokinetics is its extremely long elimination half-life, which may extend for several weeks or even months, requiring careful clinical monitoring during long-term therapy. In contrast, sotalol is characterized by relatively predictable pharmacokinetics with high oral bioavailability and minimal hepatic metabolism; it is primarily eliminated unchanged through renal excretion.

Keywords: Peculiarities, pharmacodynamics, pharmacokinetics, antiarrhythmic, medicine.

Introduction

Cardiac arrhythmias represent a heterogeneous group of electrophysiological disorders characterized by abnormalities in impulse generation, conduction, or both, leading to disturbances in the normal rhythm and rate of the heart. These conditions range from relatively benign premature contractions to life-threatening ventricular tachyarrhythmias and fibrillation, which remain significant contributors to global cardiovascular morbidity and mortality. The pharmacological management of arrhythmias has long been a cornerstone of cardiovascular therapeutics, yet it continues to present substantial clinical challenges due to the complexity of cardiac electrophysiology, the narrow therapeutic indices of many antiarrhythmic agents, and the significant risk of proarrhythmic and systemic adverse effects. Consequently, contemporary research in antiarrhythmic pharmacotherapy increasingly focuses on advanced mechanistic insights, precision dosing strategies, and integrated monitoring approaches that enhance therapeutic efficacy while minimizing safety risks.

The electrophysiological basis of arrhythmia development is intimately associated with alterations in cardiac ion channel function. Ion channels governing sodium, potassium, calcium, and mixed currents play essential roles in the generation and propagation of cardiac action potentials. Pharmacological modulation of these channels constitutes the principal mechanism through which antiarrhythmic drugs exert their therapeutic effects. Traditional classifications, such as the Vaughan Williams system, categorize antiarrhythmic agents according to their predominant electrophysiological actions on these channels. However, this framework only partially reflects the multifaceted pharmacodynamic profiles of modern antiarrhythmic compounds, many of which demonstrate pleiotropic effects across multiple ion channels, receptors, and intracellular signaling pathways. A deeper understanding of ion channel kinetics,

channelopathies, and molecular electrophysiology has therefore become central to the rational development and clinical application of antiarrhythmic pharmacotherapy.

The pharmacodynamic mechanisms, pharmacokinetic variability represents another critical determinant of antiarrhythmic drug effectiveness and safety. Factors such as absorption dynamics, hepatic and renal metabolism, plasma protein binding, and tissue distribution significantly influence drug concentrations within myocardial tissues. Genetic polymorphisms in drug-metabolizing enzymes, transport proteins, and ion channel subunits further contribute to interindividual variability in therapeutic response. These pharmacogenetic determinants are particularly relevant for antiarrhythmic agents with narrow therapeutic windows, where small fluctuations in plasma levels may lead either to therapeutic failure or to severe toxicity. As a result, personalized pharmacokinetic assessment and dose optimization strategies are becoming increasingly important components of antiarrhythmic drug therapy.

The aim of the research was to study and analyze some peculiarities of pharmacodynamics and pharmacokinetics of the antiarrhythmic medicines. Arrhythmias are irregularities in the heart's rhythm, resulting from disruptions in the electrical impulses that regulate heartbeat. These disruptions can lead to a heart rate that is too fast (tachycardia), too slow (bradycardia), or irregular. Arrhythmias range from harmless to life-threatening, and understanding their types, causes, and treatment options is crucial for effective management. Antiarrhythmic medications play a critical role in the management of arrhythmias, disturbances in heart rhythm that can lead to severe cardiovascular complications. The pharmacodynamics (PD) and pharmacokinetics (PK) of these drugs are complex and require detailed understanding for safe and effective application. This article explores the peculiarities of the pharmacodynamics and pharmacokinetics of common antiarrhythmic medications, including quinidine, amiodarone, and sotalol. Special attention is given to how factors like metabolism, drug interactions, and physiological conditions (e.g., hypokinesia) affect their efficacy and safety. Antiarrhythmic drugs are classified into several groups based on their effects on ion channels and cardiac action potentials. Their pharmacokinetics and pharmacodynamics are influenced by multiple factors, including body metabolism, enzymatic activity, and external factors such as drug interactions. This paper explores key antiarrhythmic medications and their unique PD and PK properties. The pharmacodynamics and pharmacokinetics of antiarrhythmic medications are complex and require careful consideration to avoid adverse effects. Drugs like quinidine, amiodarone, and sotalol exhibit unique characteristics in their absorption, metabolism, and elimination, which must be understood to optimize their therapeutic use.

Individual patient factors, including renal function, liver metabolism, and the potential for drug interactions, are critical to tailoring antiarrhythmic therapy effectively. Antiarrhythmic drugs are essential in the treatment of various cardiac arrhythmias, conditions characterized by abnormal heart rhythms that can lead to significant morbidity and mortality. This review explores the clinical pharmacology of these drugs, focusing on their mechanisms of action, therapeutic applications, pharmacokinetics, and potential adverse effects. By understanding these aspects, clinicians can better manage arrhythmias and optimize patient outcomes. Given the narrow therapeutic index of many antiarrhythmic drugs, interactions with other medications can have profound effects on their efficacy and safety. Amiodarone, for instance, interacts with warfarin, digoxin, and statins, increasing the risk of adverse effects. Sotalol should not be combined with other drugs that prolong the QT interval due to the heightened risk of life-threatening arrhythmias. Antiarrhythmic Drugs: such as beta-blockers, calcium channel blockers, and amiodarone, help regulate heart rhythms. However, some can have proarrhythmic effects, meaning they can cause new arrhythmias or worsen existing ones.

Arrhythmias are irregularities in the heart's rhythm, resulting from disruptions in the electrical impulses that regulate heartbeat. These disruptions can lead to a heart rate that is too fast (tachycardia), too slow (bradycardia), or irregular. Arrhythmias range from harmless to life-threatening, and understanding their types, causes, and treatment options is crucial for effective management.

Arrhythmia is a condition that affects the electrical conduction system of the heart, causing irregular heartbeats. The heart normally beats at a steady pace, controlled by electrical impulses originating from the sinoatrial (SA) node, the heart's natural pacemaker. When these impulses are disrupted, an arrhythmia can occur, which may be symptomatic or asymptomatic [1-3].

Tachycardia refers to a rapid heartbeat, usually above 100 beats per minute in adults. There are several types of tachycardia, including:

- Atrial Fibrillation (AFib): One of the most common arrhythmias, AFib occurs when rapid, disorganized electrical signals cause the atria to quiver rather than contract effectively. This can lead to blood clots, stroke, and heart failure if untreated.
- Ventricular Tachycardia (VT): A fast heart rate that originates in the ventricles, VT is potentially life-threatening, especially if it degenerates into ventricular fibrillation, which can cause sudden cardiac arrest.

Bradycardia is a slower-than-normal heart rate, usually less than 60 beats per minute. Although some athletes may have a naturally slower heart rate, bradycardia can be problematic if the heart is unable to pump enough blood to meet the body's needs.

Premature atrial or ventricular contractions (PACs or PVCs) are early heartbeats that disrupt the regular rhythm. They are common and often benign, but frequent episodes can indicate underlying heart conditions [4-6].

A heart block occurs when the electrical signals are delayed or completely blocked as they travel from the atria to the ventricles. Depending on the degree of blockage, the severity of the condition varies.

Arrhythmias are often diagnosed using an electrocardiogram (ECG or EKG), which records the heart's electrical activity. Other diagnostic tools include Holter monitors, event recorders, and electrophysiological studies (EPS) to identify the precise location of abnormal electrical activity.

Antiarrhythmic Drugs: These medications, such as beta-blockers, calcium channel blockers, and amiodarone, help regulate heart rhythms. However, some can have proarrhythmic effects, meaning they can cause new arrhythmias or worsen existing ones [8-11].

Anticoagulants: For patients with atrial fibrillation, blood thinners like warfarin or newer anticoagulants (NOACs) are used to reduce the risk of stroke by preventing blood clots. Arrhythmias are diverse in their causes, presentations, and treatments. While many arrhythmias are benign, others require medical intervention due to the risk of stroke, heart failure, or sudden cardiac arrest. Advances in medical technology, such as catheter ablation and implantable devices, have significantly improved the management of arrhythmias. Proper diagnosis and treatment are essential to minimizing risks and improving the quality of life for individuals with arrhythmias [12-14].

Antiarrhythmic drugs are essential in the treatment of various cardiac arrhythmias, conditions characterized by abnormal heart rhythms that can lead to significant morbidity and mortality. This review explores the clinical pharmacology of these drugs, focusing on their mechanisms of action, therapeutic applications, pharmacokinetics, and potential adverse effects. By understanding these aspects, clinicians can better manage arrhythmias and optimize patient outcomes [15-17].

Sodium channels there are widely present potential-dependent, potential-independent (ligand-dependent, passive, etc.) sodium channels in body cells. Sodium channels are localized in the cytoplasmic membranes of the axon hillock of neurons, dendrites and axons, in the

membrane of the perisynaptic region of the neuromuscular synapse, in the sarcolemma of striated muscle fibers and in the myocardium. The distribution density of sodium channels in these structures is different. In medical practice, the so-called substances are widely used for the blockade of fast-current sodium channels. Anesthetics (Novocaine, Dicaine, Lidocaine, Sovcaine, Procaine, etc.) [18-19].

Anesthesia is achieved by blocking sodium channels, eliminating the ability to generate nerve impulses in afferent nerve fibers, which ultimately blocks the transmission of signals from sensory pain receptors to the central nervous system. There are voltage-gated and voltage-gated potassium channels. Passive, ligand-dependent and other types of channels are distinguished among the latter. Potassium channels are found in the membranes of the same cells and tissues that contain sodium channels. Na^+ and K^+ ions are the most important cations, the distribution and movement of which determines the appearance and change of the electrical potential. More than three dozen potassium channels have been described. The family of calcium channels is widely represented in the cells of nervous and muscle tissues. The main places of their localization are membranes of presynaptic terminals of sarcoplasmic and endoplasmic reticulum of muscles, sarcolemma of cardiomyocytes and cell membranes of other tissues [21-23].

Antiarrhythmic drugs are vital for managing various cardiac arrhythmias that affect the heart's rhythm and can lead to severe complications. This comprehensive review explores the clinical pharmacology of antiarrhythmic drugs, detailing their mechanisms of action, classification, therapeutic uses, pharmacokinetics, and potential adverse effects. By understanding these aspects, healthcare professionals can optimize treatment strategies and improve patient outcomes. Antiarrhythmic drugs play a crucial role in managing various types of cardiac arrhythmias. However, their therapeutic benefits are often accompanied by a risk of toxicity, which can lead to adverse effects and complications. Understanding the toxicological profiles of these medications is essential for optimizing patient care and minimizing risks [24-25].

Metabolic regulation also plays a pivotal role in shaping the pharmacological behavior of antiarrhythmic agents. Many drugs in this class undergo extensive hepatic biotransformation through cytochrome P450 enzyme systems, generating metabolites that may possess either reduced or enhanced electrophysiological activity. Drug–drug interactions arising from enzyme inhibition or induction represent an important clinical concern, particularly in patients receiving complex polypharmacy for cardiovascular or systemic comorbidities. Furthermore, metabolic

disturbances such as electrolyte imbalances, acid–base alterations, and ischemic changes in myocardial tissue can significantly modify the electrophysiological environment in which antiarrhythmic drugs act, thereby influencing both therapeutic outcomes and adverse effect profiles.

Given these complexities, therapeutic drug monitoring and comprehensive clinical surveillance have emerged as essential strategies in modern antiarrhythmic pharmacotherapy. Continuous electrocardiographic evaluation, plasma concentration measurements, and individualized risk assessment allow clinicians to balance therapeutic benefits against potential hazards such as QT interval prolongation, torsades de pointes, conduction disturbances, and extra cardiac toxicities. Advances in digital health technologies, real-time monitoring systems, and predictive pharmacological modeling further support more precise and adaptive management of arrhythmia treatment.

The advanced pharmacological perspectives on antiarrhythmic drug therapy emphasize the integration of ion channel modulation, pharmacokinetic variability, metabolic regulation, and rigorous therapeutic monitoring into a comprehensive framework for clinical decision-making. Such an approach not only enhances the mechanistic understanding of antiarrhythmic drug action but also supports the development of safer, more individualized treatment strategies aimed at improving cardiovascular outcomes in patients with diverse arrhythmic disorders.

Goal:

The aim of the research was to study and analyze some pharmacological perspectives on antiarrhythmic drug therapy: ion channel modulation, pharmacokinetic variability, metabolic regulation, therapeutic monitoring, and clinical safety considerations.

Methods:

The material of the article was the data from scientific publications, which were processed, analyzed, overviewed and reviewed by generalization and systematization. Research studies are based on a review/overview assessment of the development of critical visibility and overlook of the modern scientific literature. Use the following databases (for extensive literature searches to identify some peculiarities of pharmacodynamics and pharmacokinetics of the antiarrhythmic medicines.): PubMed, web of science, clinical key, Tomson Reuters, Google scholar, Cochrane library, and Elsevier foundations. National and international policies and guidelines were also reviewed and as well as grey literature.

Results and discussion:

The results of the comprehensive pharmacological analysis demonstrate that antiarrhythmic drug therapy remains fundamentally dependent on the precise modulation of cardiac ion channels, while its clinical effectiveness is significantly influenced by pharmacokinetic variability, metabolic processes, and individualized therapeutic monitoring. The evaluation of electrophysiological mechanisms confirms that modulation of sodium, potassium, and calcium channels plays a central role in stabilizing cardiac electrical activity and suppressing abnormal impulse formation and conduction. Agents acting on fast sodium channels were shown to reduce the rate of depolarization in phase zero of the cardiac action potential, thereby slowing conduction velocity in atrial and ventricular myocardium. This effect contributes to the suppression of re-entry circuits that are frequently responsible for supraventricular and ventricular tachyarrhythmias. At the same time, potassium channel blockers were observed to prolong repolarization and increase the refractory period of myocardial cells, which limits the propagation of premature electrical impulses and reduces the likelihood of arrhythmia recurrence.

The investigation also highlights the importance of calcium channel modulation, particularly in arrhythmias originating from the atrioventricular node. Calcium channel inhibition reduces nodal conduction velocity and prolongs refractory periods within nodal tissue, effectively controlling ventricular rate in certain supraventricular tachyarrhythmias. The combined pharmacodynamic actions across multiple ion channels illustrate that many modern antiarrhythmic drugs exert complex electrophysiological effects rather than acting through a single molecular target. This multimodal mechanism enhances therapeutic effectiveness but simultaneously increases the potential for adverse electrophysiological consequences when drug concentrations exceed optimal therapeutic ranges.

Pharmacokinetic assessment demonstrates considerable interindividual variability in absorption, distribution, metabolism, and elimination of antiarrhythmic agents. Differences in hepatic enzymatic activity, renal function, plasma protein binding, and tissue distribution significantly influence systemic drug exposure and myocardial concentrations. The results indicate that genetic polymorphisms affecting metabolic enzymes and drug transporters contribute to marked differences in therapeutic response among patients. Individuals with reduced metabolic capacity may experience drug accumulation and an increased risk of proarrhythmic effects, whereas rapid metabolizers may exhibit subtherapeutic concentrations

and reduced antiarrhythmic efficacy. These findings underscore the growing relevance of pharmacogenetic considerations in optimizing individualized treatment regimens.

Metabolic regulation was identified as another critical determinant of antiarrhythmic drug performance. Many antiarrhythmic agents undergo extensive hepatic metabolism through oxidative pathways, producing active or inactive metabolites that influence the duration and magnitude of pharmacological effects. Drug–drug interactions were frequently observed in patients receiving concomitant cardiovascular or systemic medications, particularly those affecting cytochrome-mediated metabolic pathways. Such interactions can significantly alter plasma drug concentrations, leading either to therapeutic failure or to increased toxicity. Additionally, metabolic disturbances such as electrolyte imbalance, hypoxia, and myocardial ischemia were found to modify the electrophysiological substrate of cardiac tissue, thereby influencing the clinical effectiveness of antiarrhythmic pharmacotherapy.

Therapeutic monitoring emerged as a critical strategy for improving treatment safety and efficacy. Continuous electrocardiographic assessment allowed for early detection of conduction abnormalities, excessive QT interval prolongation, and emerging proarrhythmic patterns. Measurement of plasma drug concentrations provided additional support for dose adjustment in patients with variable pharmacokinetic profiles. The integration of clinical monitoring with pharmacological evaluation enabled more precise therapeutic control, particularly in patients with complex cardiovascular conditions or multiple comorbidities.

The findings highlight that antiarrhythmic medications possess narrow therapeutic indices and require careful clinical monitoring to balance efficacy with safety. Variability in patient-specific factors, including age, metabolic activity, hepatic and renal function, and concomitant drug therapy, significantly influences the pharmacological response to these agents. Consequently, individualized therapeutic strategies are essential to achieve optimal rhythm control while minimizing the risk of toxicity.

Antiarrhythmic drugs remain indispensable in the management of cardiac rhythm disorders, but their clinical application requires a thorough understanding of their pharmacodynamic and pharmacokinetic properties. The complexity of their mechanisms of action, metabolic pathways, and potential interactions underscores the importance of careful patient assessment and monitoring during therapy. Continued research into the molecular mechanisms of arrhythmias and the development of more selective pharmacological agents may contribute to improve therapeutic outcomes and enhanced safety profiles in the future management of cardiac arrhythmias.

Ranolazine has been shown to reduce RyR2 open probability and to desensitize Ca²⁺-dependent RyR2 activation, thereby preventing Ca²⁺ overload and EADs. Ranolazine is used for treatment of angina pectoris and ischemic heart diseases and possess clear antiarrhythmic properties. Unfortunately, ranolazine also carries an increased risk of proarrhythmic at the ventricular level by inhibiting IKr and prolonging APD and QT interval.

Carvedilol is a third-generation non-selective β -blocker with α 1-receptor blocking properties which is used as antihypertensive drug, for the treatment of heart failure with reduced ejection fraction, and in patients with ventricular dysfunction following myocardial infarction. Carvedilol and its analogues (VK-II-86, VK-II-36, CS-I-34, CS-I-59) also exhibit RyR2-blocking properties, reducing the incidence of both DADs and EADs. The effect of carvedilol may be partly due to its β -blocking and antioxidant actions, which may reduce RyR2 phosphorylation or oxidation. Interestingly, the carvedilol analogues have no or minimal β -blocking properties, but still inhibit DAD-promoting SCAEs due to a direct reduction in RyR2 open probability. Clinically used carvedilol consists of a mixture of S-and R-carvedilol enantiomers. In contrast to the S-enantiomer, R-carvedilol does not possess β -blocking properties, but specifically blocks RyR2 channels, preventing arrhythmias *ex vivo* and *in vivo* in mice. Although the preclinical studies have shown positive signals, there are no clinical data addressing the antiarrhythmic effects of carvedilol analogues [60-62].

One of the recently added atrial selective targets for potential rhythm control therapy is TASK-1. Two already well-known anti-arrhythmic drugs, namely, vernakalant and amiodarone, both inhibit TASK-1 channels. Selective TASK-1 inhibitors have also been developed and have been used in preclinical investigations. Recent *in vivo* and *ex vivo* investigations in pigs, cellular recordings from isolated human atrial cardiomyocytes, and computational modeling suggests that in the atria, the respiratory stimulant doxapram acts as a selective TASK-1 blocker with strong antiarrhythmic properties. Doxapram is currently being investigated in the Doxapram Conversion to Sinus rhythm (DOCTOS) trial for cardioversion of both paroxysmal and persistent non-valvular AF [63-64].

The development of novel AADs faces many challenges and there are many obstacles for the translation from basic discoveries to clinical applications. Besides the high regulatory hurdles and the industry concerns, the strategies used in contemporary AAD development also need careful consideration. First, the complexity of the clinical condition in which AF develops requires a tailored approach already by first clinical exposure of a novel AAD in order to have a real chance to show a positive signal. Safety concerns also play a major role because almost

all available and novel AADs possess a proarrhythmic potential. Therefore, atrial selectivity combined with minimal non-cardiac toxicity is often considered the most promising approach for the development of novel AADs for AF. However, many of the putative anti-AF targets presented above are not exclusively present in the atria. For example, although inhibition of CaMKII could be a promising anti-AF approach, CaMKII is expressed in many tissues and its inhibition could give rise to serious extra-cardiac side effects. Thus, successful drug design and appropriate formulation and application need to be carefully considered in early stage of drug development to ensure high atrial selectivity and minimal extra-cardiac effects, particularly in the brain. Atrial-specific gene therapy would be the ultimate option to ensure appropriate selectivity and besides concerns and issues that need consideration in the clinical setting an atrial-specific adeno-associated serotype 9 (AAV9) vectors has already been successfully developed and used in mice to generate efficient and atrial-specific gene expression following a single dose of systemic delivery. The development of RNA-based therapeutics is also quickly emerging [65-67].

The most promising atrial-selective drugs are those targeting TASK-1 and SK channels. TASK-1 channel inhibitors have shown promising results in preclinical studies and the first clinical trial using this approach is ongoing. Although SK channels are highly expressed in the central nervous system, the small molecules currently under development do not seem to pass the blood–brain barrier and do not exert serious neurological adverse effects in animal models or in the Phase I clinical trial. However, SK channels are not exclusively expressed in the atria of humans, suggesting only moderate atrial selectivity of SK channel inhibition. Perhaps because of this a QT prolongation was noted in the Phase I study, making further clinical investigations necessary to demonstrate the efficacy and validate the safety of SK-channel blockers [68-69].

Antiarrhythmic drugs will remain a cornerstone of rhythm control therapy for millions of AF patients. Recent studies have significantly improved our understanding of the molecular mechanisms underlying different forms of AF, identifying novel opportunities for developing mechanism-based antiarrhythmic approaches including AF-specific ion-channel blockers, targeting of Ca²⁺-handling abnormalities (CaMKII, RyR2), and modulation of upstream pathways (notably inflammatory signaling). Numerous challenges, particularly related to achieving atrial selectivity and identifying the optimal (combination of) targets for different forms of AF, still need to be overcome and well-designed clinical trials are needed to confirm safety and efficacy of these novel approaches. Nevertheless, the rapid developments in

preclinical studies on AF therapies suggest that there is still hope for novel pharmacological approaches for the most common clinically relevant arrhythmia [70-72].

Given the narrow therapeutic index of many antiarrhythmic drugs, interactions with other medications can have profound effects on their efficacy and safety. Amiodarone, for instance, interacts with warfarin, digoxin, and statins, increasing the risk of adverse effects. Sotalol should not be combined with other drugs that prolong the QT interval due to the heightened risk of life-threatening arrhythmias.

Besides direct RyR2-channel blockers, several RyR2 modulators are available or are under development. Dantrolene for instance is a RyR1 inhibitor and is clinically used to treat potentially life-threatening malignant hyperthermia. Dantrolene has also been shown to stabilize cardiac RyR2 channels by improving the inter-domain interaction between the channel N-terminal and central domains and by enhancing the binding between calmodulin and RyR2, all of which exert antiarrhythmic effects. In a sheep model of left atrial myocardial infarction dantrolene reduced the occurrence of spontaneous AF episodes. The effects of dantrolene have also been studied in isolated cardiomyocytes from patients with cAF, showing that dantrolene was able to reduce SR Ca²⁺ leak and suppress cellular DADs. Interestingly, when a CaMKII inhibitor (autocamtide-2-related inhibitory peptide, AIP) was applied in addition to dantrolene, no additive effects on the SR Ca²⁺ leak were observed. This either indicates that the effect on RyR2 is so strong that no additional benefit can be obtained by targeting CaMKII or that dantrolene has secondary direct or indirect effects on CaMKII activity. Dantrolene also reduced AF incidence in CaMKII δ C overexpressing mice. In isolated cardiomyocytes from these mice dantrolene reduced SR Ca²⁺ leak and the incidence of both DADs and EADs. These results call for additional studies investigating whether repurposing dantrolene could be an option for effectively treating AF [73-75].

Other RyR2 modulators are drugs that are capable of increasing the binding between RyR2 and its regulatory subunit calstabin2 (FKBP12.6), which acts like an endogenous RyR2-channel inhibitor by stabilizing the closed state of the channel. S107 inhibited the dissociation of calstabin2 from RyR2, reduced SR Ca²⁺ leak in mouse atrial cardiomyocytes [97-99].

Drugs targeting CaMKII are of potential interest because they target multiple effector proteins including RyR2. There are drugs in preclinical development with promising efficacy for atrial arrhythmias such rimacalib (SMP-114), RA608, hesperidin which are available for oral administration. RA608 is an ATP-competitive CaMKII inhibitor selectivity targeting the predominant cardiac forms, namely CaMKII δ and CaMKII γ . The ATP-competitiveness of

RA608 is a great advantage, as it enables the drug to bind both the active and inactive forms of CaMKII. Application of RA608 to human atrial cardiomyocytes reduces CaMKII-dependent SR Ca²⁺ leak and prevents induction of AF in mice. Rimacalib is also an ATP-competitive CaMKII inhibitor, which is currently evaluated in a clinical trial for the treatment of rheumatoid arthritis. Rimacalib reduced Ca²⁺ SR leak in human atrial and ventricular cardiomyocytes. Hesperadin is an ATP-competitive selective CaMKII δ -inhibitor that was recently shown to improve ischemia/reperfusion induced cardiac damage [76-78].

Class III AADs such as amiodarone, dofetilide and sotalol are K⁺ channel blockers that prolong ERP, thereby destabilizing re-entry. However, many Class III AADs (e.g., vernakalant, amiodarone, and its derivatives dronedarone, celicaron, budiodarone and SAR11464A) are multi-channel blockers with effects from all AAD classes. As mentioned above, the safety profiles of these AADs at the ventricular level is a major limitation hindering the development of novel AADs. The challenge with targeting the typical ERP/APD changes in cAF patients is to design drugs that prolong atrial ERP without clinically relevant pro-arrhythmic effects in the ventricles, especially in patients with ischemia and structural heart diseases, which are very common in AF patients.

The antiarrhythmic properties of SK channels have been investigated in several animal models utilizing a number of different compounds. However, the expression of the three SK-channel subtypes differs greatly between species. Moreover, SK channels undergo complex remodeling in response to a wide range of pathophysiological stimuli and the reduction in SK current during cAF observed in some studies may limit the efficacy of SK-channel blockers in certain subpopulations of cAF patients. Thus, careful evaluation of SK-channel inhibitors in well-defined patient populations will be critical. The currently leading SK-channel blocker candidate, AP30663, has proven to be safe for use in humans in phase-1 studies and has entered phase-2 clinical trials [79-81].

In the human cell membrane, there are sodium, potassium, calcium, etc. Sh. Ion channels, where Na⁺, K⁺, Ca²⁺ ions move respectively, which participate in the regulation of the body's vital processes. Ion channels ensure the excitability of the nervous system, the transmission of nerve impulses from the nerve to the muscle and the secretion of hormones, conditions our thinking, the work of the heart muscle and respiratory diaphragm, and more. That is why the blocking of the mentioned channels causes serious changes in the body. For example, the development of chronic fatigue syndrome is associated with dysfunction of the entire group of ion channels, including sodium and potassium channels [94-96].

Epilepsy is among the diseases caused by dysfunction of ion channels, which is caused by dysfunction of high-conductance potassium channels. The widespread cardiovascular disease long QT syndrome is associated with mutations in genes encoding potassium channels in the heart muscle, which increase the activity of potassium channels and change its normal flow in the heart muscle. Dysfunction of calcium channels leads to a state of ataxia, when coordination of movement is impossible. Therefore, the normal functioning of ion channels is very important for human health [82-84].

The complex intracellular signaling pathway in the body is preceded by the binding of a signaling molecule or ligand to its receptor. There are many different receptors and ligands, but they all have one thing in common, they are precisely paired. A receptor recognizes only one specific ligand, and a ligand binds to only one "target" receptor. Binding of a ligand to a receptor is followed by a change in the shape or activity of the receptor, resulting in signal transduction or a direct change in the cell. Ion channels are one of the "targets" for therapeutic agents [91-93].

The metabolism of many antiarrhythmic drugs involves the cytochrome P450 enzyme system, which introduces considerable variability in drug response among individuals. Inhibition or induction of these enzymes can lead to clinically significant drug interactions. For example, quinidine is known to inhibit CYP2D6, potentially increasing the plasma concentrations of co-administered medications metabolized by this pathway. Amiodarone interacts with numerous drugs, including anticoagulants, cardiac glycosides, and statins, thereby increasing the risk of adverse pharmacological effects. Additionally, impaired renal function may alter the elimination of drugs such as sotalol, increasing the likelihood of QT interval prolongation and proarrhythmic complications.

Antiarrhythmic drugs play a crucial role in the management of various cardiac arrhythmias, which can significantly impact patient health and quality of life. This article provides an in-depth overview of the clinical pharmacology of antiarrhythmic drugs, including their mechanisms of action, therapeutic uses, pharmacokinetics, and potential side effects. Understanding these aspects is essential for optimizing treatment and managing arrhythmias effectively. Arrhythmias, characterized by abnormal heart rhythms, are a significant concern in cardiology. Antiarrhythmic drugs are used to restore normal heart rhythm and prevent arrhythmias. This article reviews the clinical pharmacology of antiarrhythmic drugs, focusing on their classification, mechanisms of action, clinical uses, and safety considerations. Antiarrhythmic drugs are vital for the management of various arrhythmias. Understanding their

mechanisms of action, clinical applications, pharmacokinetics, and potential side effects is essential for optimizing treatment and ensuring patient safety. Continued research and clinical experience will help refine the use of these drugs and improve outcomes for patients with arrhythmias. An ion channel is a part of the membrane of a nerve cell, which carries ions, that is, positively and negatively charged. The particle provides selective permeability and participates in the regulation of the body's vital processes. It is responsible for regulating the flow of ions in the plasma and membrane of all cells, controlling the intracellular concentration of various ions. The alternating closing and opening of sodium, potassium and calcium ion channels ensures the propagation of the nerve impulse. Blockage of ion channels causes serious changes in the body. In today's medicine, a number of diseases are explained precisely by the malfunction of ion channels. Widespread pathologies in the world population: angina pectoris, arterial hypertension, arrhythmia, epilepsy, diabetes, etc. There is a small list of diseases that are caused by malfunctioning of ion channels in the human body [26-28].

Antiarrhythmic drugs are a cornerstone in the treatment of cardiac arrhythmias. Understanding their classification, mechanisms of action, pharmacokinetics, and adverse effects is essential for optimizing patient care and improving outcomes. Continued research and advancements in drug development and monitoring technologies will further enhance the management of arrhythmias and contribute to better patient outcomes. Cardiac arrhythmias are disorders of the heart's rhythm that can cause significant morbidity and mortality. Antiarrhythmic drugs are central to the management of these conditions, helping to restore and maintain normal heart rhythms. This review provides an in-depth look at the pharmacology of these drugs, examining their mechanisms, clinical applications, and the challenges associated with their use [29-31].

Amiodarone, classified as a Class III antiarrhythmic, acts by blocking potassium channels and delaying repolarization, which lengthens the refractory period of cardiac cells. Unlike other antiarrhythmic agents, amiodarone also exerts effects on sodium and calcium channels, as well as alpha and beta-adrenergic receptors, making it highly effective in treating a wide range of arrhythmias.

The pharmacodynamics of amiodarone are notable for its long half-life, as the drug can remain in the system for weeks to months. This prolonged activity, combined with its complex mechanism of action, enhances its efficacy but also increases the risk of adverse effects such as pulmonary fibrosis, liver toxicity, and thyroid dysfunction [32-33].

The pharmacokinetics of antiarrhythmic drugs vary significantly depending on their formulation and the route of administration. Quinidine, for example, exhibits rapid absorption after oral administration, with peak plasma concentrations occurring within 1-3 hours. However, its bioavailability is reduced due to first-pass metabolism in the liver.

Amiodarone's absorption is highly variable, with oral bioavailability ranging from 35% to 65%. Its lipophilic nature allows for widespread distribution in body tissues, including adipose tissue and the liver, where it can accumulate over time. Sotalol, in contrast, has excellent bioavailability but is not metabolized extensively in the liver, leading to a straightforward elimination pathway through the kidneys

Many antiarrhythmic medications are metabolized by the cytochrome P450 (CYP) enzyme system, which is subject to individual variability and can lead to significant drug interactions. Quinidine, for example, inhibits CYP2D6, increasing the plasma levels of co-administered drugs like beta-blockers and antidepressants. This increases the risk of toxicity and adverse reactions. Amiodarone is metabolized by CYP3A4 and CYP2C8, with its primary metabolite, desethylamiodarone, contributing to its antiarrhythmic activity. The long half-life of both the parent compound and the metabolite necessitates careful monitoring during long-term therapy[34-35].

Renal function plays a critical role in the elimination of certain antiarrhythmic medications, particularly sotalol. In patients with renal impairment, the elimination half-life of sotalol is prolonged, leading to increased plasma levels and a higher risk of QT prolongation and arrhythmias. Quinidine, on the other hand, is primarily excreted via hepatic metabolism, though renal elimination also contributes to its clearance.

Antiarrhythmic drugs are essential in managing cardiac arrhythmias but carry a risk of toxicity that can lead to significant complications. Understanding the toxicological profiles of these drugs and implementing appropriate management strategies are crucial for optimizing patient care and minimizing risks. Regular monitoring and dose adjustments based on individual patient needs and responses can help mitigate toxicity and ensure effective treatment [36-37].

Atrial fibrillation (AF), the most common cardiac arrhythmia worldwide, is driven by complex mechanisms that differ between subgroups of patients. This complexity is apparent from the different forms in which AF presents itself (post-operative, paroxysmal and persistent), each with heterogeneous patterns and variable progression. Our current understanding of the mechanisms responsible for initiation, maintenance and progression of the different forms of

AF has increased significantly in recent years. Nevertheless, antiarrhythmic drugs for the management of AF have not been developed based on the underlying arrhythmia mechanisms and none of the currently used drugs were specifically developed to target AF. With the increased knowledge on the mechanisms underlying different forms of AF, new opportunities for developing more effective and safer AF therapies are emerging. In this review, we provide an overview of potential novel antiarrhythmic approaches based on the underlying mechanisms of AF, focusing both on the development of novel antiarrhythmic agents and on the possibility of repurposing already marketed drugs. In addition, we discuss the opportunity of targeting some of the key players involved in the underlying AF mechanisms, such as ryanodine receptor type-2 (RyR2) channels and atrial-selective K⁺-currents (I_{K2P} and I_{SK}) for antiarrhythmic therapy. In addition, we highlight the opportunities for targeting components of inflammatory signaling (e.g., the NLRP3-inflammasome) and upstream mechanisms targeting fibroblast function to prevent structural remodeling and progression of AF. We critically appraise emerging antiarrhythmic drug principles and future directions for antiarrhythmic drug development, as well as their potential for improving AF management [38-39].

Ectopic activity arising from the PVs plays a particularly important role in pAF patients, with several potential proarrhythmic electrophysiological characteristics compared to the rest of the atria identified in animal models. However, the molecular mechanisms promoting ectopic activity in the PVs of humans remain largely unknown due to the very limited access to tissue samples. Animal models may provide valuable insight into the molecular mechanisms of pAF, but relevant animal models with spontaneous development of paroxysmal AF are scarce and the PVs do not appear to play a major role for the induction and maintenance of AF in the majority of animal models. Horses develop spontaneous AF, which can easily be detected by implantable loop recorders. Spontaneous PV firing has been recorded in horses, suggesting similar pAF mechanisms in horses and humans. However, the cellular and molecular mechanisms of ectopy have not been assessed in horses so far. Nevertheless, horses could prove to be a valuable animal for studying the true nature of Paf [40-41].

Overall, the current evidence suggests that the leading arrhythmogenic mechanism in patients with pAF is DAD-mediated ectopic activity caused by Ca²⁺-handling abnormalities without clear evidence of atrial electrical remodeling. Although atrial fibrosis could contribute, the potential role of structural remodeling in pAF patients requires further investigation and validation.

The cellular and molecular determinants of re-entry and AF maintenance are best characterized in patients with persistent AF and in animal models with artificially maintained tachycardia to simulate the arrhythmia and to study the specific effects of the high atrial rate [42-43].

Electrical remodeling in cAF or due to atrial tachycardia causes rapid ERP/APD shortening, primarily by increasing K^+ currents and reducing l-type Ca^{2+} current (ICa,L). Although the agonist-dependent acetylcholine-activated inward-rectifier K^+ current (IK_{ACh}) is decreased in cAF, it develops constitutive activity and, together with an increased basal inward-rectifier K^+ current ($IK1$) and slow delayed-rectifier K^+ current (IKs), shortens APD and hyperpolarizes resting membrane potential, promoting re-entry. The increase in $IK1$ is partly caused by increased protein expression of Kir2.1 and enhanced single-channel open probability promoted by phosphatase-dependent channel dephosphorylation. The constitutive activity of IK_{ACh} in patients with cAF is due to increased phosphorylation by protein kinase C epsilon. The functional expression of transient outward K^+ -current (Ito) is lower in cAF patients, whereas IKr is unchanged [44-46].

Some studies also reported a reduced ultra-rapid delayed-rectifier K^+ current ($IKur$) in cAF patients, while other studies did not find current alterations. Similarly, some studies revealed increased small-conductance Ca^{2+} -activated K^+ (SK) currents (ISK) in cAF, while other work showed a decreased ISK . Since the expression of SK channels and $IKur$ is larger in atrial compared to ventricular tissue, and under physiological conditions SK channels play a minor role in the ventricles, these channels are considered atrial predominant anti-AF targets. However, ventricular SK-channel expression is increased in heart failure and SK-channel inhibition can promote ventricular arrhythmogenesis under specific conditions. The atrial-specific TASK-1 channel, a member of the two-pore domain K^+ channel family, is also upregulated in cAF, contributing to APD shortening, but is downregulated in AF patients with concomitant left-ventricular dysfunction. Thus, the degree of TASK-1 remodeling in AF patients is difficult to predict. Together, the alterations in these K^+ currents likely contribute to the proarrhythmic shortening of the atrial ERP/APD in cAF patients [47-48].

The high atrial rates during AF promote a potentially toxic cellular Ca^{2+} overload. Consequently, ICa,L is reduced due to a calcineurin-dependent mechanism, contributing to re-entry-promoting APD shortening [80]. Increased nuclear Ca^{2+} releases via inositol 1,4,5-triphosphate with subsequent Ca^{2+} -calmodulin protein kinase II (CaMKII) activation accelerates the nuclear export of histone deacetylase type-4 also contributing to the

downregulation of ICa,L . ICa,L downregulation in turn reduces the Ca^{2+} -transient amplitude and atrial contractility. Ca^{2+} -handling abnormalities in cAF are primarily due to increased CaMKII activity, leading to RyR2 hyperphosphorylation at Ser2814 and leaky RyR2 channels causing potentially proarrhythmic SCAEs. Protein kinase A (PKA)-mediated RyR2 hyperpolarization at Ser2808 has also been found in cAF patients, which promotes dissociation of the stabilizing calstabin2 (FKBP12.6) subunit. SR Ca^{2+} load is unchanged in cAF patients despite the larger SR Ca^{2+} leak. This can either be due to enhanced phosphorylation of phospholamban or a downregulation of the SERCA2a-inhibitory sarcolipin. Increased PKA-mediated activation of the PP1-inhibitory protein inhibitor-1, which inhibits PP1 in the SR microdomain, could explain local phospholamban hyperphosphorylation [49-50].

Structural remodeling, particularly atrial fibrosis, makes important contributions to cAF and is largely irreversible. Besides being caused by the underlying heart disease, atrial fibrosis could result from the high atrial rate during AF. Together with connexin remodeling, collagen deposition due to atrial fibrosis creates re-entry-promoting conduction heterogeneities in cAF. Of note, myofibroblasts may also couple directly to cardiomyocytes through gap junctions, which may promote DAD-mediated triggered activity in cardiomyocytes [51-52].

Conceptually, the development of POAF requires a vulnerable preoperative substrate interacting with surgery-induced triggers such as activation of the autonomic nervous system and inflammation. The pre-existing substrate for POAF includes increased pro-inflammatory signaling, with the increased expression of activated components of the NLRP3 (NACHT, LRR and PYD domains-containing protein 3) inflammasome being the most prominent. The NLRP3 inflammasome is a multiprotein complex responsible for the cleavage and release of the pro-inflammatory cytokines IL-1 β and IL-18. Increased expression of NLRP3 inflammasome components was also identified in atrial cardiomyocytes from pAF and cAF patients, pointing to a common inflammatory signature in AF. In agreement, knock-in mice with cardiomyocyte-specific NLRP3 activation revealed an ERP abbreviation, likely due to an increase in IK_{Kur} , as well as atrial fibrosis and hypertrophy, both contributing to the increased AF susceptibility. In addition, a higher frequency of SCAEs, likely due to CaMKII-dependent RyR2-hyperphosphorylation, along with ICa,L alternans were also noted in POAF patients. Interestingly, DADs were absent under resting conditions and only became evident upon acute application of IL-1 β , mimicking one of the major post-operative inflammatory triggers. Acute IL-1 β application further promoted the CaMKII-dependent RyR2 hyperphosphorylation, thereby exacerbating the pre-existing Ca^{2+} -handling abnormalities. However, the exact

consequences of enhanced NLRP3-inflammasome activity in other types of AF, as well as in patients with obesity and diabetes, who are at an increased risk of developing AF, remain incompletely understood [53-54].

Similar to patients with pAF, patients with POAF do not display changes in APD and have no major changes in K⁺ currents. Thus, the leading mechanism in POAF appears to be ectopic (triggered) activity promoted by the acute inflammatory response without evidence of re-entry promoting APD and ERP changes, although structural changes such as connexin remodeling and fibrosis might also contribute, particularly in the left atrium.

The current ESC guidelines on management of AF focus predominantly on appropriate anticoagulation, followed by symptom control with either rate or rhythm control and management of risk factors and comorbidities. Initially, large clinical trials comparing rate and rhythm control such as Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) and Rate Control vs. Electrical Cardioversion for Persistent Atrial Fibrillation (RACE) did not find significant differences in outcome between rate and rhythm control. However, early modern rhythm control of AF might reduce the incidence of adverse cardiovascular outcomes, as shown in the Early Treatment of Atrial Fibrillation for Stroke Prevention Trial. This has again highlighted the need for improved pharmacological options for rhythm control. The challenge with traditional AADs is not only their modest efficacy, but rather their safety at the ventricular level, with ischemia and structural heart disease being a contraindication for most currently available AADs due to the high risk of drug-induced proarrhythmic. Currently used drugs are not based on knowledge of the underlying arrhythmia mechanisms and none of these drugs have been developed to specifically target AF. With the growing understanding of the fundamental mechanisms of AF it will be likely possible to develop new and improved antiarrhythmic treatment modalities based on precise knowledge of the underlying mechanisms, including upstream therapy preventing electrical and structural remodeling [55-56].

Cellular triggered (ectopic) activity is present in all forms of AF, although the silencing of atrial Ca²⁺-handling may also occur in cAF under specific conditions. In vivo, atrial ectopy may play a more important role in pAF and POAF than for patients with cAF. As described in Section 2, RyR2 channels play a major role in the Ca²⁺-handling abnormalities typically seen in AF patients. One possibility for reducing ectopic activity is, therefore, targeting abnormal RyR2 channels either by using direct RyR2-channel blockers or RyR2-function modulators.

Besides being Na⁺-channel blockers, the Class Ic AADs such as flecainide and propafenone also inhibit RyR2 channels, reducing the open probability of RyR2 in vitro via an open-state blocking mechanism (i.e., shortened duration, but increased frequency of RyR2 channel openings, thereby increasing Ca²⁺ spark mass, while reducing the occurrence of spontaneous cell-wide Ca²⁺ waves), potentially preventing the formation of proarrhythmic Ca²⁺-dependent DADs. The antiarrhythmic actions of flecainide on RyR2 channels have also been demonstrated in a cardiac casuistry knockout catecholaminergic polymorphic ventricular tachycardia (CPVT) mouse model. Moreover, a flecainide analogue that lacks RyR2-blocking properties was unable to prevent CPVT, clearly indicating that the primary mode of action of flecainide in CPVT is inhibition of RyR2. In a small clinical trial including CPVT patients, flecainide, in combination with a β -blocker, was very effective in preventing exercise-induced ventricular ectopy. In AF patients, novel routes of flecainide administration might increase cardioversion efficacy and compliance. In preclinical studies in pigs' inchoative delivery of flecainide gives rise to a similar pharmacokinetic profile to flecainide given intravenously and causes a rapid cardioversion of AF. The clinical potential of exhalative flecainide was recently tested in a clinical trial (Inhalation of Flecainide to Convert Recent Onset Symptomatic Atrial Fibrillation to sinus rhythm [57-59]).

The initiation of an AF episode requires both a trigger and a substrate. Focal spontaneous firing, also known as ectopic activity, represents the major AF-triggering mechanism. Mechanisms leading to ectopic activity include enhanced automaticity, early afterdepolarizations (EADs) and delayed afterdepolarizations (DADs). In case of enhanced automaticity, the depolarizing current during diastole is large enough to depolarize the resting membrane potential across the threshold for action potential (AP) generation, causing ectopic firing. Transient spontaneous depolarizations can also occur following complete AP repolarization, known as DADs. DADs may cause atrial ectopy if the depolarization is large enough to reach the threshold for Na⁺-channel activation and AP generation. The depolarizing current underlying DADs is created by increased Na⁺ influx through the Na⁺/Ca²⁺-exchanger (NCX), which is activated in response to spontaneous Ca²⁺-release events (SCaEs) from the intracellular stores of the sarcoplasmic reticulum (SR) through the ryanodine receptor type-2 (RyR2) channels. Finally, if the AP duration (APD) is excessively prolonged, I-type Ca²⁺ channels can be reactivated, promoting a depolarizing current during the plateau phase or early in the repolarizing phase of the AP, creating EADs [88-90].

The evolution of the arrhythmogenic substrate due to atrial remodeling is promoted by cardiac and non-cardiac diseases, risk factors such as obesity and aging, and AF itself. Atrial electrical remodeling includes Ca^{2+} -handling abnormalities and changes in ion current properties that promote re-entry by abbreviating APD and effective refractory period (ERP). Atrial structural remodeling results from atrial fibrosis, atrial dilation and connexin changes that induce re-entry-promoting heterogeneous conduction slowing [85-87].

Depending on the type of AF, the key mechanisms for initiation and maintenance of the arrhythmia differ and the type and relative contribution of triggers as well as substrates change. The proper consideration of these different mechanisms is important for the discovery of specific targets and to enable tailored therapy for each type of AF.

Atrial cardiomyocytes from patients with pAF show DAD-mediated cellular triggered activity without clear evidence for electrical remodeling such as shortening of APD or hyperpolarization of the resting membrane potential. The increased incidence of DADs in pAF patients is likely partly caused by an increased Ca^{2+} uptake into the SR by the SR Ca^{2+} -ATPase type-2a (SERCA2a) leading to enhanced SR Ca^{2+} load, along with RyR2 dysregulation [40]. The open probability of RyR2 is higher in pAF, but in contrast to patients with cAF this is associated with an increase in RyR2 expression but not channel hyperphosphorylation.

There is also evidence for the potential contribution of atrial fibrosis in pAF patients. Compared to patients in sinus rhythm, pAF patients displayed atrial fibrosis in the area of crista terminalis and the inferior pulmonary veins (PV). Similar trends were observed in the Bachman's Bundle and left atrium, albeit no significant differences were found in these regions. The pharmacodynamics and pharmacokinetics of antiarrhythmic medications are complex and require careful consideration to avoid adverse effects. Drugs like quinidine, amiodarone, and sotalol exhibit unique characteristics in their absorption, metabolism, and elimination, which must be understood to optimize their therapeutic use. Individual patient factors, including renal function, liver metabolism, and the potential for drug interactions, are critical to tailoring antiarrhythmic therapy effectively.

The results demonstrate that effective antiarrhythmic pharmacotherapy requires a multifactorial approach integrating ion channel pharmacodynamics, pharmacokinetic variability, metabolic regulation, and systematic therapeutic monitoring. Such an integrated strategy improves arrhythmia control while reducing the risks associated with proarrhythmia, drug toxicity, and treatment failure. These findings support the continued development of

personalized pharmacological strategies and advanced monitoring technologies aimed at enhancing the safety and clinical effectiveness of antiarrhythmic drug therapy.

The therapeutic success of antiarrhythmic pharmacotherapy is closely associated with the integration of electrophysiological precision and individualized clinical management. The expanded results demonstrate that patient-specific physiological characteristics, including age, cardiovascular comorbidities, structural heart disease, and systemic metabolic conditions, significantly influence both the pharmacodynamic and pharmacokinetic behavior of antiarrhythmic agents. In elderly patients and individuals with compromised myocardial function, altered drug distribution and reduced metabolic clearance frequently lead to increased plasma concentrations and heightened susceptibility to adverse electrophysiological effects. These observations highlight the importance of careful dose titration and continuous clinical evaluation when administering antiarrhythmic therapy in vulnerable patient populations.

Another important outcome of the analysis involves the relationship between myocardial cellular remodeling and pharmacological responsiveness. Chronic arrhythmogenic conditions, such as atrial fibrillation and ventricular tachycardia associated with ischemic cardiomyopathy, are often accompanied by structural and electrical remodeling of cardiac tissue. These changes include modifications in ion channel expression, alterations in intracellular calcium handling, and fibrosis-related conduction disturbances. Such pathophysiological adaptations may reduce the effectiveness of conventional antiarrhythmic drugs or modify their electrophysiological impact, thereby necessitating more advanced therapeutic strategies and careful drug selection.

The results also reveal the growing relevance of integrated monitoring technologies in optimizing antiarrhythmic treatment outcomes. Continuous electrocardiographic monitoring, advanced electrophysiological mapping, and digital cardiac rhythm analysis enable more precise detection of subtle conduction abnormalities and emerging proarrhythmic patterns. These technologies facilitate earlier therapeutic adjustments, helping clinicians prevent severe complications such as torsadogenic arrhythmias or drug-induced conduction block. Furthermore, the application of predictive pharmacological modeling and data-driven clinical decision support systems is increasingly recognized as a valuable approach for anticipating patient-specific responses to antiarrhythmic drugs.

Overall, the extended findings reinforce the concept that antiarrhythmic drug therapy cannot rely solely on traditional pharmacological principles but must instead incorporate multidimensional evaluation of electrophysiology, pharmacokinetics, metabolism, and patient-

specific risk factors. This comprehensive approach supports safer and more effective management of cardiac arrhythmias and contributes to the ongoing evolution of precision cardiovascular pharmacotherapy.

Contemporary antiarrhythmic therapy requires an integrative understanding of pharmacological mechanisms, encompassing precise ion channel modulation, interindividual pharmacokinetic variability, and metabolic regulatory pathways. Optimization of therapeutic efficacy necessitates careful monitoring of drug plasma concentrations and dynamic assessment of electrophysiological responses, ensuring maximal clinical benefit while minimizing proarrhythmic and systemic adverse effects. Advances in pharmacogenetic profiling and individualized dosing strategies further enhance patient-specific safety and therapeutic outcomes. Collectively, these insights underscore the importance of a multidisciplinary, evidence-based approach in the clinical management of arrhythmias, bridging mechanistic pharmacology with patient-centered care to achieve optimal efficacy and safety.

Conclusion

- Antiarrhythmic drug therapy remains a critical component of modern cardiovascular pharmacotherapy, yet its successful clinical application requires a comprehensive understanding of the complex interplay between electrophysiological mechanisms, pharmacokinetic variability, metabolic regulation, and patient-specific clinical factors. The present analysis highlights that modulation of cardiac ion channels continues to represent the principal pharmacodynamic foundation for the management of arrhythmic disorders. Through targeted effects on sodium, potassium, and calcium channels, antiarrhythmic agents influence cardiac action potential generation, conduction velocity, and refractory periods, thereby contributing to the stabilization of myocardial electrical activity and suppression of abnormal rhythm propagation.
- However, the therapeutic effectiveness and safety of these agents are strongly influenced by interindividual pharmacokinetic differences, including variations in drug absorption, distribution, metabolism, and elimination. Genetic polymorphisms affecting metabolic enzymes, transport systems, and ion channel structures further contribute to heterogeneity in treatment response, emphasizing the growing importance of pharmacogenetic considerations in individualized antiarrhythmic therapy. In addition, metabolic conditions, electrolyte balance, and drug–drug interactions can significantly modify the electrophysiological environment of the myocardium, potentially altering both therapeutic efficacy and the risk of adverse effects.

- The findings also demonstrate that careful therapeutic monitoring is essential for minimizing complications associated with antiarrhythmic drug administration. Continuous electrocardiographic surveillance, assessment of plasma drug concentrations, and comprehensive clinical evaluation provide important tools for early detection of proarrhythmic manifestations, conduction disturbances, and systemic toxicities. Such monitoring strategies allow timely adjustment of dosing regimens and improve the overall safety profile of antiarrhythmic pharmacotherapy.
- The future of antiarrhythmic drug therapy increasingly depends on the integration of advanced electrophysiological knowledge, pharmacokinetic optimization, metabolic risk assessment, and precision-based clinical monitoring. The adoption of personalized therapeutic strategies supported by modern diagnostic and digital monitoring technologies offers significant potential for improving arrhythmia control, reducing adverse drug reactions, and enhancing long-term cardiovascular outcomes in patients with diverse arrhythmic conditions.

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EXTENSIVELY DISSEMINATED LUMINAL B METASTATIC BREAST CARCINOMA WITH WIDESPREAD VISCERAL, SKELETAL AND CNS METASTASES: DIAGNOSTIC COMPLEXITY, MULTIMODAL IMAGING CORRELATION, THERAPEUTIC IMPLICATIONS OF CDK4/6-BASED ENDOCRINE TARGETING AND PHARMACOTHERAPY STRATEGIES (CASE STUDY)

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Abstract

Metastatic hormone receptor-positive, HER2-negative breast cancer remains a clinically heterogeneous entity, particularly in patients with aggressive luminal B biology characterized by high proliferative indices and early visceral dissemination. This case report describes an extensively disseminated presentation of grade 3 invasive ductal carcinoma with a luminal B molecular phenotype in a middle-aged female who exhibited a prolonged diagnostic delay and ultimately presented with multiorgan metastatic disease, underscoring several diagnostic, therapeutic, and prognostic challenges inherent to advanced hormone-receptor-positive disease. The patient's initial symptoms emerged years after a prior benign breast

procedure, followed by a decade of inadequate surveillance, ultimately culminating in progressive left breast changes, pain, and systemic manifestations consistent with metastatic involvement. On evaluation, targeted imaging and multimodal diagnostics demonstrated a dominant 37-mm irregular mass in the left breast with satellite lesions, multifocal disease patterns, and extensive regional nodal involvement, including internal mammary, parasternal, deep axillary, bilateral supraclavicular, and interpectoral lymphatic spread. Further staging by whole-body FDG PET/CT revealed widespread visceral and skeletal metastases, including innumerable pulmonary nodules, pleural-based lesions, mediastinal adenopathy, retroperitoneal and mesenteric lymphadenopathy, multiple hepatic masses (largest 58 × 53 mm, SUVmax 20), diffuse lytic–sclerotic skeletal metastases across axial and appendicular sites, and a metabolically active subcutaneous lesion at the umbilical level. Complementary brain MRI demonstrated millimetric contrast-enhancing metastatic foci in the cerebellum and cerebrum, as well as a suspicious occipital bone lesion, confirming central nervous system involvement at the time of presentation. Histopathologic analysis of a tru-cut biopsy identified invasive ductal carcinoma, grade 3, with low–intermediate estrogen receptor expression (33%), strong progesterone receptor positivity (95%), high Ki-67 proliferative activity (45%), and HER2-negative immunohistochemical status (score 0), corresponding to an IHC-defined luminal B subtype. The presence of E-cadherin positivity confirmed ductal lineage, while tumor-infiltrating lymphocytes were sparse (<1%), suggesting a low immunogenic profile and potentially reduced responsiveness to immunotherapy. Collectively, the molecular and histopathological features indicated an aggressive endocrine-sensitive tumor with rapid metastatic potential and high tumor burden at diagnosis. Given the extent of metastatic spread and the patient’s hormone-receptor profile, a multidisciplinary tumor board recommended initiation of contemporary first-line endocrine-targeted therapy with a CDK4/6 inhibitor–based regimen. Treatment was commenced with ribociclib in combination with letrozole and ovarian suppression via goserelin, alongside denosumab for skeletal protection. This regimen reflects current international standards for premenopausal and perimenopausal patients with HR-positive/HER2-negative metastatic breast cancer, leveraging the synergistic anti-proliferative effects of CDK4/6 inhibition and aromatase suppression. Detailed monitoring protocols focusing on hematologic parameters, hepatic enzymes, renal function, and QT interval evaluation were implemented to mitigate treatment-associated risks. Radiation oncology consultation was sought to evaluate the feasibility of stereotactic or palliative radiotherapy for intracranial and osseous metastatic lesions, in accordance with multidisciplinary care

recommendations. This case highlights several clinically relevant considerations. First, the patient's prolonged absence from routine oncologic surveillance emphasizes the critical need for sustained follow-up in individuals with prior breast abnormalities or surgical histories, regardless of earlier benign findings. Second, despite being classically considered an indolent subtype, luminal B breast cancer demonstrates a substantial propensity for early visceral involvement and rapid progression, especially in the presence of high proliferative indices. Third, the widespread distribution of metastases—including liver, lung, brain, bone, retroperitoneum, and cutaneous sites—illustrates the natural history of aggressive endocrine-sensitive breast cancer when diagnosis is delayed. Lastly, the case reinforces the central role of CDK4/6 inhibitor-based endocrine therapy in improving disease control and survival outcomes in metastatic HR-positive disease, even in the context of extensive tumor burden and CNS involvement. This extensively metastatic luminal B breast cancer case underscores the interplay between tumor biology, diagnostic delay, and the systemic spread of disease. The findings reaffirm the necessity of timely diagnostic evaluation, personalized systemic therapy selection, and integrated multidisciplinary management to optimize outcomes in patients with advanced hormone receptor-positive breast cancer.

Keywords: Luminal B breast cancer, metastatic breast carcinoma, CDK4/6 inhibitor therapy, extensive visceral metastasis, brain metastases, endocrine-targeted therapy.

Introduction

Breast cancer remains the most frequently diagnosed malignancy and the leading cause of cancer-related morbidity among women worldwide, representing a heterogeneous group of diseases defined by distinct molecular signatures, divergent clinical behaviors, and variable therapeutic responses. Among biologically classified subtypes, hormone receptor (HR)-positive, human epidermal growth factor receptor 2 (HER2)-negative tumors constitute the most prevalent category. Within this group, the luminal B subtype occupies a unique clinical position, characterized by higher proliferative activity, greater genomic instability, and more aggressive clinical behavior compared with luminal A disease. Luminal B tumors typically exhibit lower estrogen receptor (ER) expression, higher progesterone receptor (PR) heterogeneity, elevated Ki-67 proliferative indices, and frequent grade 2–3 histology, features that collectively correlate with poorer prognosis and an increased likelihood of early relapse and visceral dissemination. As molecular understanding advances, luminal B breast cancer is increasingly recognized as a distinct high-risk clinical entity requiring timely diagnosis and a strategically layered therapeutic approach [1-3].

Metastatic breast cancer (MBC) remains an incurable but treatable condition, with survival outcomes intricately influenced by tumor biology, patient factors, therapeutic accessibility, and timing of diagnosis. HR-positive/HER2-negative MBC demonstrates a predilection for bone-dominant spread; however, luminal B tumors more frequently present with visceral metastases at diagnosis, including hepatic, pulmonary, and, in advanced stages, central nervous system (CNS) involvement. The transition from early-stage to metastatic disease often evolves silently, particularly among patients with insufficient surveillance, limited access to screening, or delayed presentation. Diagnostic inertia and gaps in follow-up can permit the development of high metastatic burden and multiorgan involvement, diminishing therapeutic window and prognostic outcomes [4,5].

The presented case details the diagnostic and therapeutic complexities of advanced Luminal B metastatic breast cancer, a clinically aggressive subtype within hormone receptor-positive malignancies. Characterized by high proliferative indices and early visceral dissemination, this patient's journey underscores the profound impact of delayed diagnosis following a prior benign breast intervention. Despite initial non-malignant findings over a decade ago, prolonged absence from structured surveillance allowed for silent progression to widespread metastatic disease, involving the liver, lungs, skeleton, central nervous system, and multiple lymphatic basins at presentation [6,7].

This report highlights the critical role of multimodal imaging—including whole-body FDG PET/CT and contrast-enhanced MRI—in accurately delineating the extensive tumor burden and guiding staging. Histopathological analysis confirmed an invasive ductal carcinoma with a Luminal B phenotype, exhibiting intermediate estrogen receptor expression, strong progesterone receptor positivity, high Ki-67, and HER2-negativity. The case illustrates the shifting therapeutic paradigm in metastatic hormone receptor-positive breast cancer, wherein CDK4/6 inhibitor-based endocrine therapy, combined with ovarian suppression and bone-targeted agents, represents the contemporary standard of care [8,9].

Ultimately, this narrative emphasizes the necessity of sustained clinical vigilance, timely diagnostic evaluation, and integrated multidisciplinary management in optimizing outcomes for patients with advanced Luminal B breast cancer, while also reflecting on systemic and psychosocial barriers that contribute to delayed presentations.

Advances in imaging, including high-resolution ultrasound, contrast-enhanced breast MRI, brain MRI, and whole-body fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT), have transformed initial staging and

response monitoring in breast cancer. FDG PET/CT, in particular, provides comprehensive visualization of primary tumor metabolic activity, lymphatic spread, and distant organ involvement, enabling accurate characterization of disease biology and burden. In HR-positive/HER2-negative cases where metastatic dissemination is suspected, PET/CT and MRI are essential for identifying subtle visceral, skeletal, and CNS metastases that may not be apparent through conventional imaging. These tools also contribute to refining prognostic stratification and guiding individualized therapeutic strategies [10-12].

In recent years, targeted endocrine therapy combined with cyclin-dependent kinase 4 and 6 (CDK4/6) inhibitors has reshaped the therapeutic paradigm for HR-positive/HER2-negative metastatic breast cancer. Ribociclib, palbociclib, and abemaciclib, when integrated with aromatase inhibitors or fulvestrant, have demonstrated substantial improvements in progression-free survival and overall survival across landmark clinical trials. The combination of CDK4/6 inhibition with ovarian suppression in premenopausal and perimenopausal women has further improved disease control by achieving more profound endocrine blockade. Yet, the real-world efficacy of such regimens in patients presenting with exceptionally high metastatic burden—including widespread visceral, skeletal, nodal, and brain metastases—remains an area of ongoing clinical inquiry. Additionally, initiation of targeted endocrine therapy in patients with CNS metastases requires careful evaluation because CDK4/6 inhibitors differ in their blood–brain barrier penetration and may necessitate concurrent focal radiotherapy [14,14].

The complex trajectory of luminal B breast cancer is further compounded by variable patient-level factors and healthcare system challenges. Missed screening opportunities, failure to adhere to follow-up recommendations, and delays in symptom recognition significantly influence the stage at diagnosis. In many regions, patients who undergo benign breast procedures do not consistently remain in long-term surveillance programs, despite accumulating evidence that a subset of such individuals may harbor subclinical lesions or experience later malignant transformation. Prolonged absence from routine imaging, especially in patients with reported breast abnormalities or family history of malignancy, contributes to diagnostic delays that can enable progression to advanced-stage disease. This underscores the necessity of sustained vigilance and structured follow-up protocols even after initial benign findings [15,16].

The present case exemplifies the diagnostic and therapeutic challenges associated with delayed presentation of luminal B breast cancer. The patient, who underwent breast surgery more than a decade earlier with benign histopathology, did not adhere to recommended long-

term follow-up. Over subsequent years, she developed progressive left shoulder pain, breast erythema, swelling, and respiratory symptoms that remained uninvestigated until the disease had advanced extensively. Upon presentation, clinical evaluation revealed invasive ductal carcinoma, grade 3, with ER positivity in 33% of tumor cells, strong PR expression (95%), HER2 negativity (score 0), and a high Ki-67 index of 45%, confirming luminal B biology. The aggressive nature of this molecular subtype was evident in the rapid and widespread dissemination observed on PET/CT and MRI, which demonstrated metastases to the liver, lungs, pleura, mediastinum, retroperitoneum, mesentery, subcutaneous tissues, axial and appendicular skeleton, and multiple CNS locations [17-19].

The breadth of metastatic involvement in this case underscores the natural history of untreated or late-presenting luminal B breast cancer and highlights the importance of early multimodal evaluation. The coexistence of hepatic metastases with high metabolic activity, diffuse pulmonary nodules, extensive skeletal lytic-sclerotic lesions, bilateral supraclavicular and mediastinal lymphadenopathy, and brain micro-metastases signifies severe disease burden at initial diagnosis. Such widespread dissemination poses significant challenges for therapeutic planning and necessitates a multidisciplinary approach involving medical oncology, radiation oncology, radiology, pathology, and supportive care teams [20,21].

Given current international guidelines, initiation of ribociclib combined with letrozole, goserelin-mediated ovarian suppression, and denosumab for skeletal protection represents a rational first-line therapeutic strategy. CDK4/6 inhibitors have been shown to induce durable disease stabilization even in patients with high tumor burden, and emerging data support their integration with radiotherapy in cases of brain or bone metastases. Nonetheless, clinicians must remain vigilant for complications such as cytopenias, hepatotoxicity, QT prolongation, and treatment-associated endocrine suppression—necessitating rigorous laboratory and electrocardiographic monitoring throughout therapy [22,24].

This case provides a comprehensive illustration of the aggressive phenotype, diagnostic complexity, and therapeutic considerations associated with luminal B metastatic breast cancer, emphasizing the critical importance of timely surveillance, integrated imaging, and evidence-based systemic therapy. It highlights the potential for advanced disease evolution in the absence of regular follow-up and reinforces the need for increased awareness of luminal B biology within clinical practice, with the ultimate aim of improving patient outcomes through early detection and optimized multimodal treatment strategies [24,25].

Luminal B breast cancer occupies a biologically complex and clinically significant landscape within the spectrum of hormone receptor–positive disease. Unlike the indolent course typically associated with luminal A tumors, the luminal B phenotype demonstrates aggressive proliferative behavior, early involvement of visceral organs, and a propensity to metastasize across multiple anatomic compartments at a comparatively earlier phase of the disease course. These distinctions arise from intrinsic molecular drivers, proliferative stimuli, and pathway dysregulation, which collectively differentiate luminal B tumors from other HR-positive malignancies and position them as a high-risk subgroup requiring nuanced diagnostic vigilance and intensified therapeutic strategies.

Epidemiological and Biological Considerations

Globally, luminal B breast cancer accounts for approximately 15–25% of all invasive breast cancers, although prevalence varies significantly by geographic region, ethnicity, lifestyle exposures, and diagnostic criteria. The rising utilization of Ki-67 as a risk stratification tool, alongside evolving immunohistochemical algorithms, has led to a broader reclassification of cases once considered luminal A into the luminal B category. This reclassification has important clinical implications: patients once presumed to have relatively favorable prognoses may, in fact, harbor tumors with greater metastatic potential and require more aggressive therapy.

At the molecular level, luminal B tumors frequently demonstrate increased activation of growth factor receptor pathways, including aberrant PI3K/AKT/mTOR signaling, cyclin D amplification, increased CDK4/6–cyclin-dependent activity, and alterations in retinoblastoma (Rb) protein dynamics. These molecular signatures promote unchecked cellular proliferation, diminished sensitivity to endocrine therapy, and a greater likelihood of therapeutic resistance over time. High Ki-67 (≥ 20 –33%) remains a central biomarker of luminal B biology, signifying dysregulated cell cycle progression and correlating strongly with early relapse patterns. Clinically, these tumors often present at a higher stage, show larger primary masses, and more frequently involve multiple lymph nodes.

Patterns of Metastasis and Prognostic Challenges

The metastatic trajectory of luminal B breast cancer reflects its heightened biological aggressiveness. Compared to luminal tumors that often remain confined to bone metastases for prolonged intervals, luminal B tumors display a higher burden of visceral involvement at initial metastatic diagnosis. Hepatic metastases are particularly common and often exhibit high

metabolic activity on FDG PET/CT, reflecting elevated proliferative and glycolytic activity. Pulmonary and pleural metastases, as well as mediastinal and retroperitoneal lymphadenopathy, are observed more frequently in luminal B than in luminal disease. Importantly, while triple-negative and HER2-positive tumors exhibit the highest central nervous system metastatic rates, luminal B tumors are increasingly recognized as contributors to CNS disease, especially in cases of prolonged delay in diagnosis or when the tumor displays exceptionally high Ki-67 indices.

Bone metastases, although classical for HR-positive disease, exhibit mixed radiologic features in luminal B tumors. The interplay of osteolytic and osteoblastic processes reflects dynamic tumor-bone microenvironment disruptions mediated by RANK-L, PTHrP, interleukin signaling, and tumor-stromal crosstalk. Consequently, patients frequently present with skeletal pain, risk of pathologic fractures, and spinal instability, all requiring prompt supportive interventions such as denosumab or bisphosphonate therapy [26,27].

Delayed Presentation and Diagnostic Barriers

The case under discussion highlights an especially critical dimension in breast cancer outcomes: delayed diagnosis and incomplete longitudinal surveillance after initial benign findings. Worldwide, lapses in routine breast health monitoring—particularly after benign breast surgery, abnormal imaging, or persistent symptoms—contribute substantially to the rate of advanced-stage presentations. Psychological considerations, sociocultural dynamics, healthcare access disparities, mistrust of medical systems, and inadequate follow-up programs all play major roles in shaping patient behavior.

This patient's initial benign surgery in 2014 created a cognitive reassurance bias, reducing vigilance and diminishing follow-up adherence. Several studies have shown that individuals with prior benign breast biopsies exhibit increased risk of subsequent malignant transformation, particularly in the presence of proliferative breast disease or atypical hyperplasia. Although this patient did not have atypia reported, the absence of structured surveillance over more than a decade created an opportunity for silent tumor development and progression into an advanced metastatic stage. The gradual onset of left shoulder pain, breast erythema, and swelling were consistent early warning signs, yet these were neither evaluated nor correlated with systemic pathology until years later when the disease had already disseminated widely [28-33].

Role of Multimodal Imaging in Diagnosis and Staging

Advanced imaging is indispensable for the comprehensive assessment of metastatic breast cancer. In this case, breast ultrasonography revealed hallmark malignant features including irregular margins, high elastographic stiffness, hypoechoic heterogeneity, and ductal extensions. Elastography, which quantifies tissue stiffness, has emerged as an important adjunct, with values exceeding 150–200 kPa strongly suggestive of malignancy.

PET/CT findings were particularly remarkable, revealing simultaneous involvement of the breast, liver, lungs, lymphatic system, skeletal system, and soft tissues. The metabolic intensity of the hepatic lesions (SUVmax 20) and primary breast lesion (SUVmax 22.1) indicated highly active tumor biology, consistent with aggressive luminal B behavior. Skeletal metastases involving the spine, pelvis, ribs, and proximal femora exhibited lytic–sclerotic transitions, reflecting advanced bone remodeling and metastatic infiltration.

The brain MRI demonstrated multiple punctate enhancing foci, including cerebellar and cerebral lesions, and an occipital bone lesion suspicious for osseous skull involvement. These findings highlight the necessity of CNS evaluation in patients with high tumor burden or unusually aggressive luminal B tumors. In contemporary practice, routine brain imaging is not standard for all metastatic patients; however, growing evidence suggests that luminal B biology warrants earlier CNS screening in selected cases.

Therapeutic Landscape and Rationale for CDK4/6 Inhibition

The cornerstone of treatment for HR-positive/HER2-negative metastatic breast cancer has shifted dramatically with the advent of CDK4/6 inhibitors. Ribociclib, used in this case, has demonstrated robust efficacy in prolonging survival when combined with endocrine therapy. The MONALEESA-7 and MONALEESA-2 trials established ribociclib as one of the most effective agents for premenopausal and postmenopausal women, respectively, showing median overall survival exceeding 58–63 months in specific patient cohorts.

Mechanistically, CDK4/6 inhibitors act by arresting the cell cycle at the G1–S transition, thereby reducing proliferation driven by cyclin D1 overexpression. Luminal B tumors often exhibit increased cyclin D–CDK4/6 pathway activation due to molecular alterations involving CCND1 amplification, PI3K pathway dysregulation, and endocrine resistance mechanisms. Therefore, the therapeutic rationale for combining ribociclib with letrozole and goserelin is rooted in simultaneously suppressing estrogen-driven signaling and directly inhibiting cell-cycle progression.

Furthermore, denosumab therapy addresses the aggressive skeletal involvement noted in this patient. Its mechanism—RANK-L inhibition—reduces osteoclast-mediated bone resorption, prevents skeletal-related events, and contributes to improved quality of life.

CNS Considerations in Luminal B Disease

While CDK4/6 inhibitors have limited direct penetration across the blood–brain barrier, their systemic effects can nonetheless influence CNS disease indirectly. Abemaciclib demonstrates better CNS penetration than ribociclib or palbociclib; however, ribociclib may still play a role in controlling micrometastatic CNS disease through overall systemic reduction of tumor burden. Given this patient’s micrometastatic brain disease, multidisciplinary planning with radiation oncology is necessary to consider stereotactic radiosurgery (SRS), palliative radiotherapy, or whole-brain radiotherapy depending on lesion progression.

Clinical Implications and Need for Early Intervention

This case reinforces several essential clinical principles:

- Luminal B tumors require vigilant diagnostic monitoring due to their propensity for rapid progression.
- Diagnostic delays can result in multiorgan metastasis, particularly involving the liver, lungs, bone, and CNS.
- PET/CT should be employed early in cases with biological high-risk features or when clinical suspicion of metastasis is significant.
- CDK4/6 inhibitors represent foundational therapy but require careful monitoring for toxicities including QT prolongation and myelosuppression.
- Multidisciplinary care is indispensable, especially in patients with CNS and extensive skeletal involvement.

Breast cancer remains the most prevalent malignancy among women worldwide, representing a significant global health challenge due to its biological heterogeneity, variable clinical courses, and profound impacts on morbidity and mortality. Within this complex landscape, hormone receptor-positive (HR+), human epidermal growth factor receptor 2-negative (HER2-) breast cancers constitute the largest molecular subgroup, accounting for approximately 60-70% of all cases. These tumors, traditionally reliant on estrogen signaling for growth, have historically been associated with a more indolent behavior and responsiveness to endocrine therapies. However, this broad categorization belies a profound internal diversity, particularly between the Luminal A and Luminal B intrinsic subtypes. The latter, defined by its

distinct molecular drivers and aggressive clinical phenotype, presents a formidable diagnostic and therapeutic challenge, especially when diagnosed at an advanced, metastatic stage.

The evolution from early-stage breast cancer to metastatic disease is often a silent, insidious process. For patients with the Luminal B subtype, this progression can be particularly rapid and visceral, defying the conventional perception of HR+ disease as slowly progressive. This case report delves into the intricate narrative of a middle-aged woman with extensively disseminated Luminal B metastatic breast cancer (MBC), a presentation that starkly illustrates the catastrophic consequences of diagnostic delay, the biological ferocity of this subtype, and the modern therapeutic strategies deployed against a backdrop of overwhelming tumor burden. Her story is not merely a clinical vignette but a multidimensional exploration of the interplay between tumor biology, healthcare system gaps, psychosocial factors, and the frontiers of precision oncology.

The Luminal B Subtype: A Distinct Clinical Entity

The classification of breast cancer into intrinsic subtypes—Luminal A, Luminal B, HER2-enriched, and Basal-like—has revolutionized our understanding of the disease's natural history and therapeutic approach. Luminal B breast cancer, while sharing the HR+ hallmark with Luminal A, is a fundamentally different biological entity. It is characterized by lower expression levels of estrogen receptor (ER), often heterogeneous progesterone receptor (PR) status, higher histologic grade (commonly Grade 2 or 3), and crucially, a high proliferative index as measured by Ki-67 (typically $\geq 20\%$). Genomically, these tumors frequently exhibit increased expression of proliferation-related genes, dysregulation of growth factor pathways (notably the PI3K/AKT/mTOR and cyclin D-CDK4/6 axes), and greater genomic instability.

This aggressive molecular profile translates directly into clinical behavior. Compared to the bone-predominant, late-relapsing pattern often seen in Luminal A disease, Luminal B tumors demonstrate a marked propensity for early and widespread visceral metastasis. Involvement of the liver, lungs, and pleura is common at initial metastatic diagnosis. Perhaps more alarmingly, there is growing recognition that Luminal B biology also confers a non-negligible risk for central nervous system (CNS) metastasis, a site historically associated with more aggressive subtypes like HER2-positive and triple-negative breast cancer. This predilection for systemic dissemination, coupled with a higher likelihood of primary or acquired resistance to endocrine therapy, positions Luminal B breast cancer as a high-risk subgroup that demands heightened diagnostic suspicion and a proactive, layered treatment strategy from the outset.

The Weight of Diagnostic Delay and Lost Surveillance

A central, sobering theme in this case is the profound impact of elapsed time and lapsed surveillance. The patient's history—a benign breast procedure over a decade prior, followed by a complete absence of recommended follow-up—epitomizes a critical failure point in cancer care continuity. This scenario is unfortunately common and underscores a complex web of contributing factors: patient reassurance bias following a "benign" result, healthcare system fragmentation, and lack of structured long-term follow-up protocols for individuals with a history of breast abnormalities, and potential psychosocial barriers such as fear, denial, or competing life priorities.

The gradual onset of symptoms—left shoulder pain, breast erythema, and swelling—were likely early harbingers of locally advanced and metastatic disease. Yet, in the absence of a framework for timely re-evaluation, these signs were not investigated until they coalesced into overt, systemic illness. This delay permitted the tumor to evolve from a potentially curable early-stage lesion into a widely disseminated, stage IV malignancy. The resulting tumor burden, as captured by advanced imaging, is staggering: a dominant breast mass with multifocal spread, extensive lymphatic invasion across multiple nodal basins, and metastases to the liver, lungs, bones, CNS, retroperitoneum, mesentery, and even subcutaneous tissue. This case thus serves as a powerful, cautionary testament to the necessity of sustained vigilance. It argues compellingly for the implementation of robust, personalized surveillance strategies for individuals with any history of breast abnormality, recognizing that a past benign finding does not confer lifetime immunity and may, in fact, signal a breast at heightened risk.

The Imperative of Comprehensive Staging in High-Risk Disease

Faced with a presentation suggestive of aggressive biology or advanced disease, conventional staging with computed tomography (CT) and bone scan may be insufficient. This case highlights the indispensable role of advanced multimodal imaging in the accurate initial staging and subsequent management of Luminal B MBC. Whole-body fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) has emerged as a cornerstone for this purpose. It provides a holistic, metabolic map of the disease, simultaneously evaluating the primary tumor, nodal status, and distant metastases. The high standardized uptake value (SUVmax) observed in this patient's primary breast lesion (22.1) and hepatic metastases (20) is not merely a quantitative measure but a biomarker of aggressive tumor biology, reflecting heightened glycolytic activity and proliferative drive characteristic of Luminal B tumors.

Furthermore, the detection of millimetric CNS metastases on brain MRI—a finding that might have been missed or delayed without a high index of suspicion—fundamentally alters the therapeutic landscape. It introduces the need for multidisciplinary coordination with radiation oncology and influences the choice of systemic therapy, given the variable blood-brain barrier penetration of different agents. The integration of breast MRI with elastography further refines the local assessment, characterizing tissue stiffness as an adjunctive marker of malignancy. This comprehensive imaging approach does more than just stage; it risk-stratifies, reveals the true extent of the biological threat, and provides essential baseline data for assessing response to therapy.

Therapeutic Paradigm Shift: CDK4/6 Inhibition as the Backbone of Care

The management of HR+/HER2- MBC has undergone a transformative shift in the past decade with the advent of cyclin-dependent kinase 4 and 6 (CDK4/6) inhibitors. Drugs like ribociclib, palbociclib, and abemaciclib, when combined with endocrine therapy, have consistently demonstrated unprecedented improvements in progression-free survival and overall survival across multiple pivotal clinical trials (e.g., MONALEESA, PALOMA, and MONARCH). This patient's treatment regimen—ribociclib combined with the aromatase inhibitor letrozole, ovarian suppression with goserelin, and the bone-targeted agent denosumab—epitomizes the contemporary, evidence-based first-line standard for premenopausal/perimenopausal women with advanced disease.

The scientific rationale is deeply rooted in the biology of Luminal B tumors. The frequent dysregulation of the cyclin D-CDK4/6-retinoblastoma (Rb) pathway in this subtype creates a therapeutic vulnerability. CDK4/6 inhibitors act by arresting the cell cycle at the G1/S checkpoint, directly countering the unchecked proliferation that defines these cancers. When combined with endocrine therapy, which aims to deprive the tumor of its estrogenic growth signal, a synergistic anti-tumor effect is achieved. This combination represents a paradigm of targeted therapy, moving beyond mere hormonal blockade to precise interference with the cell cycle machinery itself.

However, the initiation of such potent therapy in the context of extraordinary disease burden, as seen here, introduces unique challenges. It tests the real-world efficacy of these regimens in patients often excluded from clinical trials due to poor performance status or extensive visceral/CNS disease. It necessitates meticulous supportive care and monitoring for class-specific toxicities: myelosuppression (particularly neutropenia), hepatotoxicity, QT interval prolongation (specific to ribociclib), and managing the side effects of profound

estrogen deprivation. The concurrent use of denosumab addresses the pervasive skeletal metastases, aiming to prevent skeletal-related events like fractures and spinal cord compression, thereby preserving quality of life.

Multidisciplinary Care: The Non-Negotiable Framework

The complexity of this case, with its CNS involvement, symptomatic bone disease, and high systemic burden, makes it unequivocally clear that no single specialty can manage such a patient in isolation. Optimal care is inherently multidisciplinary. The medical oncologist orchestrates the systemic therapy. The radiation oncologist evaluates the role of stereotactic radiosurgery for brain metastases or palliative radiotherapy for painful bone lesions. Radiologists provide critical interpretive nuance for complex imaging. Pathologists ensure accurate biomarker characterization. Supportive care/palliative medicine specialists address pain, nausea, fatigue, and psychological distress. This integrated, collaborative model is essential not only for crafting an initial treatment plan but also for navigating the inevitable twists, toxicities, and progressions of the disease course. It ensures that therapeutic decisions are holistic, considering not just tumor metrics but also patient symptoms, quality of life, and personal goals.

Broader Implications: From a Single Case to Systemic Reflection

While this report details an individual journey, its implications resonate across the broader domains of oncology practice, public health, and research.

- **Clinical Practice:** It mandates a recalibration of risk perception for HR+ disease. Clinicians must internalize that Luminal B is a high-risk subtype warranting urgency in diagnosis, comprehensive staging, and aggressive first-line therapy. It argues for the early use of PET/CT in clinically high-risk scenarios and consideration of baseline brain imaging in patients with extensive visceral metastases or highly proliferative Luminal B tumors.
- **Healthcare Systems:** The case is a stark indictment of fragmented follow-up. It calls for the development and implementation of standardized, risk-adapted surveillance protocols for patients with a history of benign breast disease, leveraging registries and digital reminders to prevent patients from being lost to follow-up.
- **Psychosocial Dimensions:** It highlights the need for better patient education, communication, and support to overcome barriers to care. Reassurance after a benign result must be carefully balanced with clear guidance on the importance of ongoing vigilance and prompt reporting of new symptoms.

- **Research Frontiers:** This presentation points toward future directions. Could circulating tumor DNA (ctDNA) analysis have detected molecular relapse years before radiographic evidence? Will genomic profiling of metastatic lesions reveal targetable resistance mechanisms (e.g., ESR1 mutations, PI3K pathway alterations) to guide subsequent therapies? What is the optimal integration of local therapies (radiation, surgery) with CDK4/6 inhibitors for oligometastatic or oligoprogressive disease? How can artificial intelligence enhance early detection on imaging?
- The journey of this patient with extensively metastatic Luminal B breast cancer serves as a profound, multidimensional case study. It underscores the aggressive natural history of this biologic subtype, the dire consequences of diagnostic and surveillance failures, the critical importance of state-of-the-art imaging, and the transformative potential of modern, biology-driven systemic therapy. Most importantly, it reinforces that in the face of such complex advanced cancer, hope and improved outcomes lie in a triad of principles: timely recognition fueled by clinical awareness, precision intervention guided by molecular understanding, and compassionate, integrated care delivered by a dedicated multidisciplinary team. The battle against metastatic breast cancer is fought on these three fronts simultaneously, and this case vividly maps the terrain of that challenging, yet increasingly manageable, conflict.

Healthcare System and Psychosocial Dimensions

Late-stage presentations often reflect gaps not only in individual health-seeking behaviors but also in structural healthcare limitations. Limited patient education on breast cancer symptoms, inconsistent follow-up protocols, financial barriers, and healthcare fragmentation all contribute to advanced presentations. Psychosocial factors—including denial, fear of diagnosis, prioritization of family responsibilities, and stigma—may further delay timely medical assessment. For many women, especially those with prior benign pathology, reassurance from past negative findings can overshadow new symptoms and prevent early re-evaluation.

Implications for Clinical Practice and Future Directions

This case illustrates critical future directions in breast oncology:

- **Enhanced post-benign-surgery surveillance protocols** should be standardized.
- **Incorporation of molecular risk profiling** at earlier stages may refine follow-up intensity.
- **Emerging biomarkers**, including circulating tumor DNA (ctDNA), may enable earlier detection of recurrence or metastasis.

- **Integration of precision oncology approaches**, such as genomic sequencing of metastatic lesions, may guide targeted therapies beyond CDK4/6 inhibitors, including PI3K inhibitors, AKT inhibitors, and antibody–drug conjugates.
- **Artificial intelligence–assisted imaging analysis** may improve early recognition of subtle metastatic lesions.

Case Presentation

A middle-aged female presented with a several-year history of progressive left shoulder discomfort, intermittent breast swelling, and increasing erythema of the left breast. These symptoms evolved slowly over the preceding four years but remained uninvestigated. Her medical history was notable for a benign breast surgery performed in 2014 following breastfeeding, after she had detected firmness in the left breast. Although she had been advised to attend biannual follow-up, she did not continue surveillance and remained without clinical evaluation for more than a decade. Past surgical history included a total abdominal hysterectomy with left oophorectomy and a recent appendectomy performed less than one month before the current oncologic assessment. She had no known chronic illnesses and no documentation of hereditary breast cancer risk.

On presentation, she exhibited marked asymmetry of the breasts with erythema, firmness, and palpable abnormality in the lower inner quadrant of the left breast. The skin showed no ulceration or peau d'orange changes, and the nipple–areolar complex remained anatomically preserved. Palpation of the left shoulder elicited discomfort, corresponding to her long-standing symptom. There was no clinical evidence of acute respiratory distress; however, she reported dyspnea on exertion. No neurological deficits were noted on examination.

Initial ultrasonography of the left breast revealed a solid, irregularly contoured mass measuring $37 \times 24 \times 33$ mm in the lower inner quadrant, demonstrating markedly increased stiffness on elastography with a mean measurement of 180 kPa. The lesion displayed a thick peripheral halo, heterogeneous hypoechogenicity, and a tubular extension of approximately 20 mm extending toward the nipple, suggestive of ductal infiltration. Multiple additional small, irregular hypoechoic foci were visualized medial and inferomedial to the dominant lesion, the largest being 14×4 mm, raising suspicion for multifocal malignant involvement. Additional small lobulated hypoechoic areas in the upper inner quadrant were considered likely fibroadenomatoid or multicentric foci. Several interpectoral lymph nodes were detected, the largest measuring 8×3 mm, suspicious for metastatic involvement. No clearly pathologic lymph nodes were seen in the left axilla. The right breast demonstrated several small, smooth,

hypoechoic lesions considered benign, but cortical thickening in right axillary lymph nodes warranted additional evaluation.

A core needle biopsy of the dominant lesion confirmed invasive ductal carcinoma of no special type, high grade, with Nottingham grade 3 morphology. Immunohistochemical analysis demonstrated estrogen receptor expression in 33 percent of tumor cells with weak to moderate staining intensity, progesterone receptor expression in 95 percent of tumor cells with strong staining, HER2 negativity with a score of zero, and a Ki-67 proliferative index of 45 percent, consistent with a luminal B, HER2-negative molecular subtype. E-cadherin positivity supported ductal lineage, and tumor-infiltrating lymphocytes were markedly sparse, involving less than one percent of the tumor area. Specimen handling conformed to ASCO/CAP guidelines.

Given the clinical suspicion of advanced disease, a whole-body FDG PET/CT scan was performed. The left breast mass displayed intensely increased metabolic activity with a SUVmax of 22.1, accompanied by an adjacent satellite focus. Extensive lymphatic involvement was noted, including the left internal mammary chain, parasternal nodes, deep axillary nodes, bilateral supraclavicular nodes, and mediastinal, paratracheal, hilar, retroperitoneal, para-aortic, mesenteric, and paracaval lymph nodes. Pulmonary evaluation revealed numerous hypermetabolic nodules within both lungs accompanied by pleural thickening, consistent with widespread pulmonary and pleural metastases. Multiple hypodense hepatic lesions demonstrated intense FDG uptake, the largest measuring 58 × 53 mm with a SUVmax of 20, indicating substantial visceral tumor burden. A hypermetabolic subcutaneous lesion at the umbilical level measuring 14 mm in diameter was also identified. The skeletal survey demonstrated extensive lytic and sclerotic metastatic involvement throughout the cervical, thoracic, and lumbar vertebrae, ribs, pelvis, sacrum, and both proximal femora, with SUV values up to 14.4.

Because PET imaging suggested intracranial involvement, a contrast-enhanced brain MRI was obtained. Several millimetric enhancing lesions were observed in the cerebellar hemispheres and cerebral cortex, including a 3 mm parietal lesion and a 2 mm frontal lesion. Additional punctate enhancing foci were identified in the right frontal region, and an ill-defined post-contrast opacity in the occipital bone raised concern for osseous metastatic disease. No mass effect, hydrocephalus, or compromise of the posterior fossa structures was present.

Based on the integrated clinical, radiologic, and pathologic findings, the patient was diagnosed with extensively disseminated metastatic luminal B breast carcinoma involving the breast, lymphatic system, liver, lungs, pleura, bones, brain, retroperitoneum, mesentery, and

subcutaneous tissues. After multidisciplinary tumor board discussion, treatment was initiated with ribociclib in combination with letrozole and ovarian suppression using goserelin, along with denosumab for skeletal protection. A structured monitoring plan was established including serial laboratory testing, ECG evaluation for QT interval assessment, and repeat PET/CT imaging after three months to evaluate treatment response.

Clinical Findings

At presentation, the patient appeared in a generally preserved condition but reported progressive left shoulder pain, breast swelling, and intermittent erythema that had intensified over the previous months. Inspection of the left breast revealed visible asymmetry with localized skin erythema over the lower inner quadrant, though there was no ulceration, peau d'orange change, or nipple inversion. Palpation identified a firm, irregular mass deep within the lower inner quadrant of the left breast, associated with mild tenderness. The overlying skin retained normal pliability, and no discharge or architectural distortion of the nipple–areolar complex was observed.

Palpation of regional lymphatic basins revealed small, firm nodules in the left interpectoral region, suggestive of nodal involvement, while the left axilla did not demonstrate clearly enlarged or fixed lymph nodes. On the right side, axillary examination identified lymph nodes with palpable cortical thickening, although they were mobile and not overtly suspicious on physical assessment alone.

Musculoskeletal examination elicited pain on manipulation of the left shoulder, corresponding to the patient's long-standing symptom. No deformity or restriction of range of motion was identified, although deep palpation reproduced discomfort, raising suspicion of underlying osseous involvement. The patient did not exhibit focal neurological deficits, sensory loss, visual disturbance, or cerebellar signs at the time of clinical examination, despite the later-confirmed presence of micrometastatic brain lesions on imaging.

Pulmonary examination revealed mildly reduced breath sounds at the left lung base without crackles, wheezing, or dullness to percussion. She reported episodic exertional dyspnea but denied resting shortness of breath. Cardiovascular and abdominal examinations were unremarkable, and no hepatosplenomegaly, ascites, or palpable masses were detected.

The overall constellation of findings—breast asymmetry with a dominant palpable mass, regional nodal changes, musculoskeletal pain localized to the shoulder, and mild respiratory symptoms—raised strong suspicion for an advanced primary breast malignancy with potential systemic involvement. These clinical features prompted comprehensive imaging

and histopathologic evaluation, which confirmed the presence of extensively disseminated luminal B breast carcinoma.

Diagnostic Assessment

The patient underwent comprehensive diagnostic evaluation following clinical suspicion of advanced breast malignancy. Initial breast ultrasonography of the left breast demonstrated a dominant solid mass in the lower inner quadrant measuring $37 \times 24 \times 33$ mm, characterized by irregular, infiltrative contours, pronounced peripheral hypoechoic halo, and internal heterogeneity. Shear-wave elastography revealed markedly increased tissue stiffness with a mean value of 180 kPa, reinforcing the suspicion of a malignant process. A tubular extension toward the nipple, measuring approximately 20 mm, was consistent with ductal infiltration. Additional smaller hypoechoic foci medial and inferomedial to the primary lesion suggested multifocal disease. In the upper inner quadrant, several small lobulated hypoechoic areas were identified, interpreted as possible fibroadenomatoid or multicentric foci. Sonographic evaluation of regional lymphatic basins revealed multiple suspicious interpectoral lymph nodes, the largest with cortical thickening; however, no overtly abnormal lymph nodes were identified in the left axilla. Right axillary nodes demonstrated mild cortical thickening, prompting further correlation with advanced imaging.

A core needle biopsy of the dominant lesion was performed. Histopathological examination confirmed invasive ductal carcinoma of no special type with Nottingham grade 3 morphology. Immunohistochemical analysis demonstrated estrogen receptor positivity in 33 percent of tumor cells with weak to moderate staining, strong progesterone receptor expression in 95 percent of cells, and HER2 negativity with a score of zero. The Ki-67 index was elevated at 45 percent, consistent with a highly proliferative luminal B, HER2-negative subtype. E-cadherin staining confirmed ductal differentiation, and the tumor microenvironment was notable for sparse tumor-infiltrating lymphocytes, comprising less than one percent of the tumor area. All specimen handling parameters were compliant with ASCO/CAP recommendations.

Given the possibility of extensive systemic involvement, whole-body FDG PET/CT was performed, revealing a highly metabolic left breast mass with a SUVmax of 22.1. The scan demonstrated widespread metastatic dissemination. Multiple hypermetabolic nodal regions were present, including the left internal mammary, parasternal, deep axillary, bilateral supraclavicular, right paratracheal, pre-carinal, hilar, retroperitoneal, para-aortic, mesenteric, and paracaval chains. Pulmonary evaluation showed numerous bilateral pulmonary nodules and pleural thickening, all displaying increased tracer uptake. The liver contained multiple

hypodense, FDG-avid lesions, and the largest in the posterior superior segment of the right lobe measuring 58×53 mm with a SUVmax of 20. A hypermetabolic subcutaneous nodule at the umbilical level, measuring 14 mm with a SUVmax of 5.7, was also noted. Extensive lytic–sclerotic skeletal metastases were distributed throughout the cervical, thoracic, and lumbar vertebrae, ribs, pelvis, sacrum, and proximal femora with SUV values up to 14.4.

Because PET/CT findings suggested possible intracranial involvement, contrast-enhanced brain MRI was conducted. The study revealed several millimetric enhancing metastatic foci within the superior cerebellar hemispheres, a 3 mm nodular lesion in the right parietal lobe with peripheral enhancement, a 2 mm lesion in the right frontal lobe, and additional punctate lesions in the anterior frontal region. An ill-defined contrast-enhancing opacity in the anterior right occipital bone raised suspicion for osseous skull metastasis. No abnormalities were identified in the ventricular system, posterior fossa morphology, brainstem, or major intracranial vessels.

Collectively, the diagnostic assessments confirmed the presence of an aggressive, extensively disseminated luminal B invasive ductal carcinoma with simultaneous metastases to the liver, lungs, pleura, bone, brain, retroperitoneum, mesentery, lymphatic system, and subcutaneous tissues. The concordant imaging and histopathological findings established the diagnosis of stage IV breast carcinoma with an exceptionally high tumor burden, guiding the multidisciplinary team toward endocrine-targeted systemic therapy with CDK4/6 inhibition as first-line management.

Therapeutic Intervention

Following confirmation of extensively disseminated luminal B breast carcinoma with widespread visceral, skeletal, lymphatic, and intracranial involvement, the patient's case was reviewed by a multidisciplinary tumor board comprising medical oncology, radiation oncology, radiology, pathology, and supportive care specialists. Given the hormone receptor–positive, HER2-negative profile and high proliferative index, a consensus was reached to initiate contemporary first-line endocrine-targeted therapy incorporating CDK4/6 inhibition. This strategy was selected to provide optimal disease control while maintaining a favorable toxicity profile in the setting of significant tumor burden.

Systemic therapy was commenced with ribociclib administered orally once daily for twenty-one days followed by a seven-day rest period, in combination with continuous daily letrozole as the aromatase inhibitor backbone. Ovarian function suppression was initiated using monthly subcutaneous goserelin to ensure complete estrogen deprivation, given the patient's

premenopausal or perimenopausal endocrine status. This combination regimen reflects current international standards of care for hormone receptor–positive, HER2-negative metastatic breast cancer and is supported by robust evidence demonstrating improvements in progression-free and overall survival, particularly in patients with high-risk biological features such as elevated Ki-67 indices.

Given the extensive skeletal involvement with mixed lytic–sclerotic metastatic lesions affecting the axial and appendicular skeleton, denosumab was initiated as a bone-modifying agent. Monthly subcutaneous administration was selected to reduce the risk of skeletal-related events including pathological fractures, spinal instability, and severe cancer-associated bone pain. The patient was counseled on calcium and vitamin D supplementation to mitigate the risk of hypocalcemia.

To ensure safe administration of ribociclib and early recognition of potential adverse effects, a comprehensive monitoring plan was established. Baseline and pre-cycle electrocardiograms were obtained to evaluate QT interval dynamics, recognizing the known risk of QT prolongation associated with ribociclib. Laboratory surveillance included complete blood counts to detect neutropenia, liver function tests to monitor for hepatotoxicity, and renal parameters to assess treatment tolerance. The patient was educated extensively regarding signs of infection, hepatotoxicity symptoms, and the importance of adherence to scheduled laboratory assessments.

Radiation oncology evaluated the feasibility of early intervention for intracranial micrometastases and symptomatic bone lesions. Given the small size and lack of mass effect of the brain lesions, stereotactic radiosurgery was considered contingent upon evidence of progression or the development of neurological symptoms. Palliative radiotherapy remained an option for pain control should skeletal symptoms intensify during systemic therapy.

The overall therapeutic approach prioritized rapid systemic disease control while integrating local modalities as clinically indicated. This comprehensive management strategy aimed to address the extensive tumor burden, alleviate symptoms, prevent foreseeable complications, and maintain the patient’s functional status while closely monitoring treatment response through scheduled follow-up imaging.

Patient Follow-Up Summary

Clinical Background:

The patient is diagnosed with metastatic breast carcinoma with documented metastases involving the liver, lungs, bones, and brain. Hormone receptor and proliferation status are as follows: ER 33%, PR 95%, HER2-negative (score 0), Ki-67 45%. Systemic therapy with ribociclib, letrozole, goserelin, and denosumab was initiated on 20XX.

Past Medical and Surgical History:

In 2014 following breastfeeding, the patient noted firmness in the left breast and subsequently underwent surgical intervention. No malignancy was detected at that time. Despite recommendations for biannual follow-up, she did not attend scheduled monitoring visits. Over the past four years, experienced persistent pain localized to the left shoulder. She developed erythema and swelling in the left breast. Concurrently, fluid accumulation was identified in the lung. Pelvic MRI revealed osseous lesions suggestive of metastatic involvement.

Her surgical history includes total abdominal hysterectomy and left oophorectomy performed. Additionally, she underwent appendectomy 24 days prior to the current evaluation.

Pathology Report

Specimen: Left breast, 37 mm solid lesion, BIRADS 5

Procedure: Tru-cut core biopsy

Diagnosis:

- Invasive ductal carcinoma, Not Otherwise Specified (NOS)

Histologic Grade:

- Grade 3 (Nottingham Histologic Score)

Molecular Classification (IHC4):

- Luminal B, HER2-negative subtype

Immunohistochemical Profile:

1. Estrogen Receptor (ER):

- Positive
- Nuclear staining in 33% of cells
- Average staining intensity: weak to moderate

2. Progesterone Receptor (PR):

- Positive
- Nuclear staining in 95% of cells

- Average staining intensity: strong

3. **Ki-67 Proliferative Index:** 45%

4. **HER2 Status (IHC):**

- Negative (score 0)
- No membranous staining observed

❖ **Diagnosis**

Specimen: Left breast, 37 mm solid lesion, BIRADS Category 5

Procedure: Tru-cut core biopsy

❖ **Histopathological Findings:**

- **Invasive ductal carcinoma, Not Otherwise Specified (NOS)**
- **Histologic Grade (Nottingham):** Grade 3

❖ **Molecular Classification (IHC4):** Luminal B, HER2-negative

Immunohistochemical Profile:

1. **Estrogen Receptor (ER):**

- Positive
- Nuclear positivity in 33% of tumor cells
- Average staining intensity: weak to moderate
- Primary antibody clone: SP1

2. **Progesterone Receptor (PR):**

- Positive
- Nuclear positivity in 95% of tumor cells
- Average staining intensity: strong
- Primary antibody clone: 1E2

3. **Ki-67 Proliferative Index:** 45%

4. **HER2 Status:**

- Negative (score 0)
- No membranous staining observed
- Primary antibody clone: 4B5

❖ **Test Methodology:** Immunohistochemistry (IHC) was performed using validated primary antibody clones for ER, PR, and HER2 as listed above.

❖ **Additional Pathology Findings:**

❖ Ki-67:

- Proliferative index 45%
- Primary antibody clone: MIB1

❖ Specimen Handling:

- Cold ischemia time and fixation duration are appropriate according to ASCO/CAP guidelines.

❖ E-cadherin:

- Positive in tumor cells, consistent with ductal epithelial phenotype.

❖ Tumor-Infiltrating Lymphocytes (TILs):

- Less than 1% of the tumor area

❖ Macroscopic Description:

- Five tru-cut core biopsy specimens were received, ranging in size from 0.1 cm to 1 cm in length.
- One T1C + 1 HE slide prepared.
- Specimen labeling: TT/ZK

❖ PET/CT Findings:

PET imaging demonstrated abnormal hypermetabolic activity in the following regions, consistent with disseminated malignancy:

- Mass lesion in the upper inner quadrant of the left breast and an adjacent satellite lesion.
- Multiple lymph nodes in the left internal mammary chain, left deep axillary region, and bilateral supraclavicular regions.
- Multiple nodular lesions within both lung parenchyma, pleural thickening, and pleural-based nodules.
- Multiple mediastinal lymph nodes.
- Hypodense hepatic lesions demonstrating increased uptake.
- Retroperitoneal lymphadenopathy.
- Subcutaneous nodular lesion at the umbilical level.
- Multiple diffuse lytic–sclerotic skeletal lesions.

These findings collectively support widespread metastatic disease.

Brain MRI was ordered for further assessment, and pathology results were pending at that time.

❖ Planned Treatment:

Systemic therapy with ribociclib, letrozole, goserelin, and denosumab is scheduled. A consultation with radiation oncology has been requested for further evaluation and treatment planning.

Bilateral Breast Ultrasonography Report:

❖ Left Breast Findings

General Observations:

- Skin, subcutaneous tissue, nipple, and areola are normal; no skin thickening or retraction is noted.

Lesions:

1. Lower inner quadrant (11 AM, peripheral, palpable site):

- Solid mass measuring 37 × 24 × 33 mm
- Irregular contours, thick peripheral halo
- High stiffness on elastography (mean 180 kPa)
- Tubular extension toward nipple (~20 mm) with heterogeneous hypoechoic appearance suggestive of dilated ducts
- Central punctate echogenicities possibly representing calcifications
- Morphologically considered malignant; percutaneous biopsy recommended

2. Inferomedial and medial to main mass:

- Multiple irregular hypoechoic foci
- Largest 14 × 4 mm; others 9 × 4 mm
- Considered potentially significant for multifocal disease

3. Upper inner quadrant (Periareolar and deep locations):

- Hypoechoic areas: 14 × 7 mm, 5.5 mm, 5 mm
- Smooth lobulated margins
- Possible **fibroadenomatoid changes** or **multicentric foci**

Lymph Nodes:

- Interpectoral region: multiple lymph nodes, largest 8 × 3 mm, suspicious for malignancy (possible Rotter's ganglion involvement)
- Left axilla: no pathologic lymph nodes detected

❖ Right Breast Findings

Lesions:

- 11 AM: 12×3 mm, hypoechoic, smooth margins, ovoid, partially angulated margins (possible fibroadenoma)
- 3 PM, periareolar: 4×2 mm, hypoechoic, smooth, ovoid (fibroadenomatoid hyperplastic area or dense cyst)
- 10 PM, peripheral: 6×3 mm, hypoechoic, smooth, ovoid (dense cyst or fibroadenomatoid change)

Lymph Nodes:

- Right axilla, inferior (level I): two adjacent lymph nodes with asymmetric cortical thickening, largest 14×8 mm
- PET/CT correlation recommended for further evaluation

❖ Impression**1. Left breast lower inner quadrant (10 AM):**

- Solid mass $37 \times 24 \times 33$ mm with irregular contours and morphologic features suggestive of malignancy
- Tubular extension toward nipple, 20 mm, suggestive of dilated ducts
- Multiple irregular hypoechoic foci inferomedial and medial to mass, potentially indicating multifocal disease
- Recommendation: Histopathological confirmation via percutaneous biopsy

2. Left breast upper inner quadrant:

- Small, smooth, lobulated hypoechoic areas, possible fibroadenomatoid or multicentric foci

3. Left interpectoral lymph nodes:

- Suspicious nodes present; largest 8×3 mm

4. Right breast:

- Three hypoechoic lesions, largest 12×3 mm, partially angulated margins
- Likely fibroadenomatoid or benign; correlation recommended

5. Right axilla:

- Two adjacent lymph nodes with cortical thickening, largest 14×8 mm; PET/CT recommended

❖ BI-RADS Assessment:

- Category 5: Highly suggestive of malignancy
- Additional imaging and histopathologic correlation necessary

❖ Brain MRI Report

Examination Type:

Brain MRI with contrast.

❖ Findings

Metastatic Lesions:

- Superior medial left cerebellar hemisphere and superior right cerebellar hemisphere: millimetric punctate contrast-enhancing metastatic foci
- Right parietal lobe: 3 mm nodular lesion with peripheral contrast enhancement
- Right frontal lobe: 2 mm nodular lesion with dense opacity and two additional punctate contrast-enhancing foci anteriorly
- Anterior right half of occipital bone: ill-defined post-contrast opacity, suspicious for osseous metastasis

Cerebellum and Brainstem:

- Morphology of posterior fossa, medullocervical junction, medulla oblongata (olivary and pyramidal regions), pons, and cerebellar peduncles is normal
- Prepontine, cerebellopontine, and perimesencephalic cisterns are patent
- Fourth ventricle size and location are normal

Diencephalon and Midline Structures:

- Mesencephalic tectum, cerebellar peduncles, thalamus, and other diencephalic structures show normal morphology
- Basal ganglia, corpus callosum, and other midline structures appear normal

Other Intracranial and Skull Base Structures:

- Main intracranial vessels, cranial nerve pairs, optic chiasm, sella and parasellar regions, temporal bones, orbits, paranasal sinuses, and other skull base structures are within normal limits

Impression

- Multiple cerebral and cerebellar metastatic nodular lesions, largest measuring 3 mm, with peripheral contrast enhancement
- Right occipital bone opacity suspicious for metastatic involvement
- No additional abnormality detected in brain parenchyma, ventricular system, or skull base
- Recommendation: Follow-up MRI to assess lesion progression and treatment response

❖ **Tumor FDG PET/CT Study Report**

❖ **Technique**

Whole-body PET/CT imaging was performed from the vertex to mid-femur, 60 minutes after intravenous administration of **7.9 mCi F-18 FDG**. The patient had been fasting for 15 hours prior to injection, with a measured blood glucose level of 106 mg/dL.

For anatomical localization, CT images were obtained, and oral contrast (water) was administered immediately before and 33 minutes after FDG injection to facilitate bowel visualization. Axial, coronal, and sagittal PET images were acquired and reconstructed using iterative reconstruction techniques and correlated with CT slices for anatomical reference.

❖ **Findings**

❖ **Brain:**

- Evaluation limited due to patient head movement.
- Right frontal region: 6 mm focus of increased FDG uptake relative to contralateral symmetry.
- Recommendation: Correlation with brain MRI is advised to further characterize this lesion.

Cervical and Supraclavicular Lymph Nodes:

- Bilateral inferior cervical and supraclavicular lymph nodes demonstrate increased FDG uptake.
- Largest lymph node measures 12 mm (SUVmax: 8–11.2).

Left Breast and Regional Lymph Nodes:

- Upper inner quadrant mass: 32 × 25 mm with markedly increased FDG uptake (SUVmax: 22.1).
- Associated lymph nodes:
- Parasternal and internal mammary regions: multiple lymph nodes with abnormal uptake
- Left axillary and deep axillary regions: several lymph nodes, largest 9 mm, showing increased activity

Right Breast and Axillary Region:

- Right axillary lymph node: 9 mm, SUVmax 3.3
- Right breast parenchyma demonstrates fibrocystic changes without focal FDG uptake
- Recommendation: Clinical and radiological correlation advised

Thorax:

- Bilateral pulmonary nodular lesions and pleural thickening demonstrate abnormal increased FDG uptake (SUVmax: 7.6)

Mediastinum and Thorax:

- Multiple lymph nodes along the right paratracheal chain, anterior mediastinum, precarinal region, bilateral hilar, and interlobar regions show abnormal FDG uptake (SUVmax: 14.6), suggestive of metastatic involvement.

Liver:

- Multiple hypodense lesions within the liver parenchyma
- Largest lesion: posterior superior segment of the right lobe, measuring 58 × 53 mm, SUVmax: 20
- SUV of normal-appearing liver parenchyma: 3.7

Retroperitoneum and Abdomen:

- Multiple lymph nodes at the diaphragm level: retroperitoneal, para-aortic, mesenteric, and paracaval regions with abnormal FDG uptake (SUVmax: 14.2)
- Subcutaneous nodular lesion at umbilicus level, 14 mm in diameter, SUVmax: 5.7

Skeletal System:

- Multiple lytic-sclerotic lesions throughout the skeleton with abnormal FDG uptake
- Involvement includes cervical, thoracic, and lumbar vertebrae; ribs; pelvic bones (most prominent in sacrum); and bilateral proximal femora
- SUVmax: 14.4

Other Findings:

- FDG activity in other body regions demonstrates normal physiological distribution

Conclusions

- ❖ **Primary Breast Lesion:** Left breast upper inner quadrant mass and adjacent satellite focus show abnormal FDG uptake, consistent with malignancy.
- ❖ **Lymph Node Involvement:**
 - Left internal mammary and deep axillary nodes
 - Bilateral supraclavicular nodes
 - Mediastinal, retroperitoneal, para-aortic, mesenteric, paracaval lymph nodes
 - Right paratracheal and hilar nodes
 - Left and right axillary nodes

- ❖ **Pulmonary Lesions:** Nodular lesions in bilateral lung parenchyma and pleural thickening with increased FDG uptake
- ❖ **Hepatic Lesions:** Multiple hypodense hepatic lesions with high FDG uptake
- ❖ **Subcutaneous Lesion:** Nodular lesion at umbilicus with FDG avidity
- ❖ **Skeletal Metastases:** Multiple lytic-sclerotic lesions throughout cervical, thoracic, lumbar vertebrae, ribs, pelvis, sacrum, and proximal femora
- ❖ **Overall Impression:** Findings are consistent with **widespread metastatic disease** originating from left breast carcinoma.
- ❖ **Impression**
 - **Left breast mass (upper inner quadrant) with high FDG avidity** (SUVmax 22.1), consistent with known malignancy.
 - **Regional lymphadenopathy:** Parasternal, internal mammary, left axillary, deep axillary, and right axillary lymph nodes with abnormal FDG uptake suggestive of metastatic involvement.
 - **Pulmonary and pleural lesions:** Multiple nodular lesions with high FDG uptake, consistent with metastatic disease.
 - **Brain:** Right frontal FDG-avid lesion noted; MRI correlation recommended.
 - Findings consistent with **multifocal metastatic breast carcinoma**; clinical, histopathological, and radiological correlation is advised for comprehensive staging and management.
- ❖ **Treatment Schedule**
 - ✓ Following multidisciplinary tumor board consensus, a systemic endocrine-targeted treatment strategy incorporating CDK4/6 inhibition was initiated as first-line therapy for hormone receptor–positive, HER2-negative metastatic breast carcinoma with extensive visceral, skeletal, and CNS involvement. The treatment plan was designed to achieve maximal systemic disease control while minimizing treatment-related toxicity and preserving functional status.
 - ✓ The patient commenced therapy with a CDK4/6 inhibitor–based regimen combined with endocrine suppression and bone-targeted therapy. Ribociclib was administered orally in a cyclical schedule of 21 consecutive days followed by a 7-day rest period, constituting a 28-day treatment cycle. Letrozole was administered continuously on a daily basis as the aromatase inhibitor backbone. Given the patient’s premenopausal/perimenopausal status, ovarian function suppression was achieved using monthly subcutaneous goserelin to ensure

complete estrogen deprivation. In parallel, denosumab was initiated for skeletal protection due to extensive lytic–sclerotic bone metastases, with concurrent calcium and vitamin D supplementation.

- ✓ Baseline assessments included complete blood count, liver and renal function tests, serum electrolytes, and electrocardiography for QT interval evaluation. These assessments were repeated at regular intervals in accordance with ribociclib safety monitoring recommendations. Imaging reassessment with FDG PET/CT was planned after three treatment cycles to evaluate metabolic and anatomical response, while brain MRI follow-up was scheduled based on clinical evolution and multidisciplinary recommendations.
- ✓ Radiation oncology consultation was obtained for evaluation of intracranial micrometastases and symptomatic skeletal lesions. Local radiotherapy was reserved for disease progression, symptom escalation, or neurological compromise.

Medical Oncology Chemotherapy Schedule Form

Diagnosis:

Luminal B, HER2-negative metastatic invasive ductal carcinoma of the breast with widespread visceral, skeletal, lymphatic, and CNS metastases

Treatment Intent:

Palliative, disease-controlling systemic therapy-Table-1.

Treatment Component	Drug	Dose	Route	Schedule
CDK4/6 inhibitor	Ribociclib	600 mg	Oral	Once daily, Days 1–21 of a 28-day cycle
Aromatase inhibitor	Letrozole	2.5 mg	Oral	Once daily, continuous
Ovarian suppression	Goserelin	3.6 mg	Subcutaneous	Every 28 days
Bone-modifying agent	Denosumab	120 mg	Subcutaneous	Every 4 weeks
Supportive therapy	Calcium + Vitamin D	Standard supplementation	Oral	Daily

Monitoring Plan: Table-2.

Parameter	Frequency
Complete blood count	Baseline; Days 1 and 15 of Cycle 1; prior to each subsequent cycle
Liver function tests	Baseline; every cycle
Renal function and electrolytes	Baseline; every cycle
ECG (QT interval assessment)	Baseline; Day 14 of Cycle 1; prior to Cycle 2; then as clinically indicated

Parameter	Frequency
Imaging (FDG PET/CT)	After 3 cycles or as clinically indicated
Brain MRI	As per multidisciplinary recommendation or neurological symptoms

Planned Duration of Therapy:

Treatment to be continued until disease progression, unacceptable toxicity, or patient preference, with regular multidisciplinary reassessment.

Prescribed Regimen:

Ribociclib–Letrozole–Goserelin–Denosumab therapy

Ribociclib: Three tablets (1 × 3) should be taken simultaneously each morning, either on an empty stomach or after a meal. The patient will take the medication for 21 consecutive days, followed by a 7-day treatment break.

Monitoring Requirements:

At the beginning of each new treatment cycle, the following evaluations are required: cardiology assessment with QT interval measurement, complete blood count, urea, creatinine, ALT, AST, and bilirubin levels.

Letrozole: One tablet (1 × 1) taken daily.

Denosumab: Administer subcutaneously once every 28 days.

Goserelin: Administer subcutaneously once every 28 days.

Follow-Up: A PET scan is recommended after 3 months of therapy to assess treatment response.

Discussion

This case illustrates the complex natural history and aggressive clinical trajectory of luminal B breast cancer when diagnosis is significantly delayed and surveillance is interrupted. Although hormone receptor–positive, HER2-negative tumors are generally considered more indolent than other biological subtypes, the luminal B phenotype represents a distinct, high-risk entity defined by elevated proliferative activity, genomic instability, and an increased likelihood of early visceral metastasis. The patient’s presentation with simultaneous metastases to the liver, lungs, pleura, skeleton, lymphatic basins, retroperitoneum, mesentery, subcutaneous tissue, and brain underscores the potential aggressiveness of this subtype, particularly when early symptoms remain uninvestigated for prolonged periods.

The diagnostic delay in this case played a pivotal role in disease progression. Following a benign breast procedure in 2014, the patient entered a long period without recommended biannual follow-up. The absence of surveillance allowed for the silent development and

unchecked spread of malignancy. The gradual onset of left shoulder pain beginning several years before diagnosis likely represented early skeletal involvement and remained an overlooked clinical clue. Similarly, progressive breast erythema and swelling emerged months before presentation but were not evaluated. These missed diagnostic opportunities highlight the importance of structured long-term follow-up for women with a history of breast abnormalities—even when pathology is benign—particularly in regions where healthcare fragmentation or patient-level barriers impede consistent surveillance. The case reinforces that benign findings do not confer long-term protection from malignancy and that continued clinical vigilance remains essential.

From a diagnostic standpoint, multimodal imaging played a transformative role in revealing the true breadth of metastatic disease. Ultrasonography provided initial confirmation of a suspicious mass with hallmark malignant features, including irregular margins, significant elastographic stiffness, ductal extension, and multifocal satellite lesions. However, it was whole-body FDG PET/CT that delineated the full systemic burden, demonstrating intensely hypermetabolic hepatic lesions, innumerable pulmonary nodules, pleural disease, extensive nodal involvement from the cervical to retroperitoneal regions, lytic–sclerotic skeletal metastases, and metabolically active subcutaneous involvement. PET/CT is increasingly recognized as superior to conventional CT and bone scan in staging patients with biologically aggressive, high-proliferation breast cancers; the metabolic intensity in this case, with SUV_{max} values exceeding 20 in both the breast and liver, reflects rapid tumor growth and glycolytic activity characteristic of luminal B biology. Brain MRI further identified multiple punctate cerebral and cerebellar metastases and a suspicious occipital bone lesion, highlighting the necessity of intracranial evaluation in patients with heavy systemic tumor burden. Although CNS involvement is more commonly associated with HER2-positive or triple-negative disease, emerging evidence shows that luminal B tumors with high proliferation indices and extensive visceral spread may also carry significant risk for brain metastases.

The histopathological profile corroborated the aggressive nature of the disease. The tumor demonstrated high-grade morphology with a Ki-67 index of 45 percent, reduced estrogen receptor expression, strong progesterone receptor positivity, and HER2 negativity. This combination aligns with luminal B categorization and indicates increased reliance on proliferative pathways, including cyclin D–CDK4/6–Rb signaling, PI3K/AKT/mTOR dysregulation, and potential genomic drivers of endocrine resistance. The near-complete absence of tumor-infiltrating lymphocytes suggests a low-immunogenic microenvironment,

which may limit responsiveness to immune checkpoint inhibitors. This profile reinforces the importance of targeted endocrine strategies as the backbone of therapy in such patients.

The therapeutic approach adopted in this case mirrors the current paradigm shift in the management of metastatic hormone receptor–positive, HER2-negative breast cancer. CDK4/6 inhibitors, particularly ribociclib, combined with aromatase inhibition and ovarian suppression, have become the global standard of care due to their proven survival advantage in high-risk populations. Randomized trials have demonstrated marked improvements in both progression-free and overall survival with ribociclib-based regimens, especially in premenopausal and perimenopausal women. The mechanism of action, centered on inhibition of CDK4/6-mediated progression through the G1–S phase of the cell cycle, directly targets the proliferative hallmark of luminal B tumors. In this patient, where both biological aggressiveness and metastatic extent were pronounced, the selection of ribociclib was rational and evidence-supported. Additionally, denosumab was initiated to address the substantial skeletal involvement, leveraging its ability to inhibit RANKL-mediated osteoclast activity and prevent skeletal-related events.

A notable challenge in patients with widespread metastases and CNS involvement is determining the optimal integration of systemic and local therapies. Although CDK4/6 inhibitors have limited blood–brain barrier penetration, the systemic reduction in tumor burden may exert indirect control over micrometastatic CNS disease. Abemaciclib has demonstrated somewhat higher CNS penetration, but ribociclib remains appropriate when paired with radiotherapy as needed. In this case, stereotactic radiosurgery was considered for future progression of intracranial lesions or development of neurological symptoms. The strategy of prioritizing systemic control before local CNS intervention aligns with current practice for asymptomatic, small-volume brain metastases.

This case also underscores broader implications for healthcare systems and patient education. Diagnostic delays often stem from a combination of reassurance bias following benign findings, lack of structured follow-up programs, socioeconomic constraints, limited access to imaging, or psychosocial factors such as fear or denial. The evolution from early-stage disease to widely metastatic cancer in this patient highlights the consequences of such systemic and behavioral barriers. Improving patient adherence to surveillance, enhancing breast health literacy, and integrating follow-up reminders or navigational support may mitigate similar outcomes in comparable populations.

This case of extensively disseminated luminal B metastatic breast cancer exemplifies the interplay between biological aggressiveness, missed opportunities for early diagnosis, and

the critical role of modern multimodal imaging and targeted systemic therapy. It reinforces the necessity of continuous vigilance following any breast abnormality, the importance of early recognition of evolving symptoms, and the centrality of CDK4/6 inhibitor–based endocrine therapy in managing high-risk metastatic hormone receptor–positive disease. The case further illustrates that even in the presence of overwhelming tumor burden, a coordinated, multidisciplinary therapeutic strategy can offer meaningful disease control and optimize patient outcomes.

The clinical trajectory of the patient presented here, characterized by an advanced Luminal B metastatic breast cancer (MBC) with diffuse systemic dissemination, serves as a critical focal point for a multifaceted discussion that extends far beyond a singular case report. It compels an examination of the evolving understanding of Luminal B biology, the persistent and systemic challenges in early diagnosis, the nuanced application of modern therapeutics in complex real-world scenarios, and the future directions necessary to alter the course of this high-risk disease. This discussion aims to dissect these interconnected themes, drawing upon the case as a paradigm to explore the contemporary and future landscape of managing aggressive hormone receptor-positive breast cancer.

Luminal B Biology: Redefining "Indolent" Hormone Receptor-Positive Disease

The historical dichotomy that categorized HR+ breast cancer as "indolent" and HER2-positive or triple-negative as "aggressive" is now recognized as an oversimplification with potentially dangerous clinical consequences. This case powerfully challenges that outdated paradigm. The tumor's immunohistochemical profile—ER 33%, PR 95%, HER2-negative, Ki-67 45%—is the signature of a Luminal B neoplasm, a subtype that occupies a distinct and perilous niche.

The aggressive phenotype observed is rooted in its molecular architecture. Unlike Luminal A tumors, which are largely driven by estrogen signaling alone, Luminal B cancers frequently harbor co-activating alterations that fuel proliferation independent of estrogen. These include amplification of *CCND1* (encoding cyclin D1), activating mutations in the *PI3KCA* pathway, and dysregulation of other growth factor receptors. The high Ki-67 index of 45% is not merely a laboratory value; it is a direct readout of uncontrolled cell cycle progression, driven in part by the very cyclin D-CDK4/6-Rb pathway that is the target of this patient's therapy. This intrinsic proliferative drive explains the "high-volume, high-metabolic" presentation: the large, FDG-avid primary tumor (SUV_{max} 22.1), the rapidly growing hepatic metastases (SUV_{max} 20), and the astonishingly widespread dissemination at diagnosis.

Furthermore, the pattern of metastasis is telling. While bone involvement is classic for HR+ disease, the synchronous, heavy burden of visceral (liver, lung, pleura) and central nervous system metastases signifies a tumor with extraordinary metastatic efficiency and plasticity. This pattern aligns with emerging data suggesting that Luminal B tumors, particularly those with high Ki-67, may possess biological traits that facilitate extravasation and colonization of visceral organs and potentially the CNS microenvironment. The presence of subcutaneous and retroperitoneal metastases further underscores a capacity for dissemination beyond the classic "first-stop" sites, painting a picture of a systemic disease process that was operative long before clinical detection.

The Cascading Consequences of Diagnostic Delay: A Systems Failure Analysis

The decade-long interval between the patient's benign procedure and her metastatic presentation is the pivotal, tragic element of this case. This delay cannot be attributed to a single cause but rather represents a cascade of failures across multiple levels: individual, clinical, and systemic.

At the individual and psychosocial level, "reassurance bias" is a potent force. A past benign diagnosis can create a false sense of security, leading patients to downplay or rationalize new symptoms. Left shoulder pain may be attributed to musculoskeletal strain; breast erythema to a minor infection. This is compounded by fear, denial, and the overwhelming psychological burden of potentially facing a cancer diagnosis. For many women, particularly those with family or work responsibilities, seeking medical attention for vague symptoms may be deprioritized.

At the clinical level, the absence of a mandated, structured, and personalized long-term follow-up protocol for patients with a history of benign breast abnormalities is a glaring gap. While screening guidelines exist for the general population and for high-risk individuals (e.g., *BRCA* carriers), there is no universally adopted standard for the substantial cohort of women who have undergone biopsies or surgeries for benign findings. The recommendation for "biannual follow-up" given to this patient was likely vague and, without a system to enforce or facilitate it, was easily neglected. The primary care provider, possibly unaware of the nuanced risk associated with a past breast procedure, may not have proactively pursued surveillance.

At the systemic level, this case highlights issues of healthcare fragmentation, access, and inequity. The patient "fell through the cracks" between surgical care and ongoing primary or specialized oncology surveillance. In many healthcare environments, particularly those with

resource constraints or where patients bear significant out-of-pocket costs, regular imaging follow-up is unsustainable. Furthermore, public health messaging often emphasizes *de novo* screening (mammography) but may under-communicate the importance of *surveillance* for those with a personal breast history.

The result, as seen here, is a "perfect storm" that allows a biologically aggressive tumor an uncontested runway to progress from a localized, potentially curable state to a life-limiting, systemic illness. The economic and human cost of managing stage IV disease—with its complex drug regimens, frequent imaging, and supportive care needs—is exponentially greater than that of treating early-stage cancer, making investment in robust surveillance systems not only an ethical imperative but also a potential economic one.

The Role of Advanced Imaging: Beyond Staging to Biological Interrogation

The diagnostic workup in this case exemplifies the transition from conventional to comprehensive, biology-informed staging. The use of breast ultrasound with elastography provided not just morphology but also a biomechanical property (stiffness >180 kPa), which is strongly correlated with malignancy. This functional data adds a layer of diagnostic confidence beyond the BIRADS 5 categorization.

The whole-body FDG PET/CT, however, was the cornerstone. Its value extends far beyond merely counting metastases. The quantitative metabolic data (SUV_{max}) serves as an *in vivo* biomarker of tumor aggressiveness. The high SUV in the liver and primary tumor provided immediate, visual confirmation of the high proliferative index suggested by Ki-67. PET/CT also revealed the true, shocking extent of nodal disease—involving internal mammary, parasternal, and retroperitoneal stations—that would have been incompletely assessed by CT alone. This comprehensive map is indispensable for several reasons:

- **Accurate Prognostication:** The burden of disease, especially liver and CNS involvement, is a key determinant of prognosis.
- **Therapeutic Planning:** It identifies all sites requiring potential local intervention (e.g., radiotherapy for symptomatic bone lesions or CNS metastases).
- **Baseline for Response Assessment:** It provides a sensitive benchmark against which the metabolic response to CDK4/6 inhibitor therapy can be measured at the 3-month interval.

The complementary brain MRI, which identified millimetric enhancing foci, underscores a critical practice point. In patients with Luminal B MBC presenting with high visceral burden, particularly hepatic metastases, there is a growing argument for considering baseline brain imaging. While not yet a universal standard, this approach can detect

asymptomatic CNS disease, allowing for timely intervention with stereotactic radiosurgery, which is more effective and better tolerated than whole-brain radiotherapy used for symptomatic, bulky disease.

CDK4/6 Inhibitors in the Real World: Efficacy, Challenges, and Synergies

The initiation of ribociclib + letrozole + goserelin represents the gold-standard first-line therapy. Landmark trials like MONALEESA-7 have shown median overall survival exceeding 58 months in pre/perimenopausal women with HR+/HER2- MBC. However, the patient population in this case pushes the boundaries of "real-world" application. Clinical trials often exclude patients with extensive liver metastases, life-threatening visceral disease, or untreated brain metastases. Therefore, the robust efficacy seen in trials must be cautiously extrapolated to such extreme presentations.

The mechanistic rationale, however, is compelling. By combining deep endocrine blockade (ovarian suppression + aromatase inhibition) with direct cell cycle arrest via CDK4/6 inhibition, this regimen attacks the two core pillars of Luminal B tumor growth. The hope is that this powerful dual attack can induce rapid disease control, even in high-burden settings, potentially reversing organ dysfunction and buying critical time.

Yet, this approach is fraught with management challenges:

- **Toxicity Vigilance:** The need for monitoring QT interval, liver function, and neutrophil counts is paramount. Neutropenia, while common, is typically not associated with the same high risk of febrile neutropenia as chemotherapy. However, in a patient whose marrow may already be stressed by extensive bone metastases, close hematologic monitoring is essential.
- **CNS Disease Management:** Ribociclib has limited blood-brain barrier penetration. The management of the identified brain micrometastases therefore requires a separate, synergistic strategy. Stereotactic radiosurgery (SRS) is the preferred modality, offering high local control with minimal neurocognitive side effects. The systemic therapy aims to control extracranial disease and potentially prevent new CNS seeds, while SRS ablates existing visible foci. This exemplifies the essential integration of medical and radiation oncology.
- **Skeletal Morbidity:** The diffuse lytic-sclerotic bone disease places the patient at high risk for skeletal-related events (SREs) such as pathologic fracture, spinal cord compression, and severe pain. Denosumab, a RANK-L inhibitor, is more potent than bisphosphonates in preventing SREs and is a critical component of supportive care, working in concert with systemic therapy to preserve skeletal integrity and quality of life.

The initial treatment response, to be assessed by PET/CT at 3 months, will be highly informative. A significant metabolic response would validate the potency of this regimen even in advanced settings. However, primary resistance is a possibility, potentially driven by *ESR1* mutations, *RBI* loss, or alternate pathway activation, which would necessitate a rapid switch to second-line options like fulvestrant, another CDK4/6 inhibitor, or chemotherapy.

The Indispensable Multidisciplinary Tumor Board (MDT)

This case could not be managed effectively without a formal Multidisciplinary Tumor Board (MDT). The MDT moves decision-making from a sequential, specialist-centric model to a concurrent, integrative one. In this setting:

- The medical oncologist presents the systemic therapy plan and manages its toxicities.
- The radiation oncologist evaluates the brain and bone metastases for potential palliative or consolidative radiotherapy, discussing the timing and technique (e.g., SRS vs. conventional palliative RT) in relation to systemic therapy.
- The radiologist reviews the nuances of the imaging, distinguishing post-treatment changes from progression.
- The pathologist confirms the biomarker status and discusses the potential for further genomic testing on the biopsy specimen (e.g., next-generation sequencing for *PI3KCA*, *ESR1*) to guide future therapy.
- The palliative/supportive care specialist addresses pain management (likely from bone metastases), antiemetics, fatigue, and psychological distress, ensuring quality of life is central to the care plan.

This collaborative model minimizes therapeutic gaps, avoids contradictory recommendations, and ensures the patient receives a coherent, evidence-based, and compassionate treatment strategy tailored to her specific disease distribution and personal circumstances.

Future Directions and Evolving Paradigms

Looking forward, this case illuminates several critical pathways for improving outcomes for patients with Luminal B breast cancer:

- **Risk-Adapted Surveillance:** Future guidelines must move towards personalized surveillance protocols. A woman with a history of a benign breast lesion, especially if it showed proliferative changes, and a subsequent decade without imaging, should be considered for more intensive monitoring than the general population. This could involve annual breast MRI or contrast-enhanced mammography, potentially guided by risk

prediction models that incorporate histologic and molecular features of the initial benign tissue.

- **Liquid Biopsies and Minimal Residual Disease (MRD):** The analysis of circulating tumor DNA (ctDNA) holds immense promise. In a patient like this, had she been under surveillance, periodic ctDNA testing could have detected molecular relapse months or even years before radiographic recurrence, triggering imaging and allowing for intervention at a far earlier, potentially oligometastatic stage. In the metastatic setting, ctDNA can monitor response in real-time, detect emerging resistance mutations (e.g., *ESR1*), and guide therapy switches before clinical progression.
- **Precision Oncology Beyond CDK4/6 Inhibition:** While CDK4/6 inhibitors are the backbone, resistance is eventual. Genomic profiling of a metastatic biopsy (or ctDNA) can reveal subsequent actionable targets. For tumors with *PI3KCA* mutations, alpelisib (a PI3K α inhibitor) combined with fulvestrant is a validated option. For those with *ESR1* mutations, novel oral Selective Estrogen Receptor Degraders (SERDs) are in development. Antibody-drug conjugates like sacituzumab govitecan (Trodelvy), though currently approved in triple-negative breast cancer, are showing activity in heavily pre-treated HR+ disease and may play a future role.
- **Integrating Local Therapies in Oligometastatic/Oligoprogressive Disease:** As systemic therapies improve, controlling limited sites of progression with surgery or radiotherapy ("metastasis-directed therapy") can prolong the benefit of a given systemic regimen. While this patient presented with frankly polymetastatic disease, future patients detected earlier via improved surveillance may present with oligometastatic Luminal B cancer, where aggressive local treatment of all sites combined with systemic therapy could aim for long-term disease control or even "no evidence of disease" status.
- **Addressing Health System and Psychosocial Barriers:** Ultimately, technological and pharmacological advances must be coupled with systemic reforms. This includes implementing patient navigation programs to guide individuals through complex care pathways, developing standardized follow-up algorithms embedded in electronic health records, improving patient education about the significance of persistent symptoms, and addressing the financial toxicity of cancer care to ensure equity in access to these life-prolonging treatments.

The case of this patient with extensively metastatic Luminal B breast cancer is a poignant synthesis of modern oncologic challenge and opportunity. It forces a reckoning with

the aggressive potential of a subtype too often glossed over within the broader "HR-positive" category. It exposes dangerous fissures in our post-diagnostic surveillance systems. Simultaneously, it showcases the powerful diagnostic tools and targeted therapies now at our disposal—weapons that were absent a generation ago.

Her management plan, centered on CDK4/6 inhibition and multidisciplinary care, represents the current apex of evidence-based practice. Yet, her story is ultimately a call to action. It argues for a paradigm shift from reactive treatment of advanced disease to proactive, intelligent prevention of metastatic progression. This requires harnessing molecular insights for risk stratification, implementing technology-driven surveillance, and building healthcare systems that do not allow patients to disappear from care. The goal must evolve from simply prolonging survival in stage IV to preventing the development of stage IV altogether. By learning from cases like this one—by understanding the biology, acknowledging the systemic failures, and aggressively applying both existing and emerging tools—we can work towards a future where the devastating presentation described herein becomes a historical relic rather than a contemporary reality.

THERAPEUTIC IMPLICATIONS OF CDK4/6-BASED ENDOCRINE TARGETING AND PHARMACOTHERAPY STRATEGIES

The advent of cyclin-dependent kinase 4 and 6 (CDK4/6) inhibitors has fundamentally redefined the first-line therapeutic landscape for hormone receptor-positive (HR+), HER2-negative metastatic breast cancer (MBC). Their integration with endocrine therapy (ET) represents a paradigm shift from sequential hormonal manipulation to a proactive, synergistic blockade of both the estrogen signaling and cell cycle proliferation pathways. The presented case of extensively metastatic Luminal B breast cancer provides a critical lens through which to examine the profound implications, practical challenges, and strategic nuances of this cornerstone treatment approach.

Biological Rationale and Synergistic Mechanism

The therapeutic rationale for CDK4/6 inhibition is deeply rooted in the molecular biology of Luminal B tumors. This subtype is frequently characterized by dysregulation of the cyclin D-CDK4/6-retinoblastoma (Rb) pathway, often due to *CCND1* amplification or activation of upstream signals from the PI3K/AKT/mTOR pathway. This dysregulation leads to hyperphosphorylation of Rb protein, releasing E2F transcription factors and driving unchecked progression from the G1 to the S phase of the cell cycle.

CDK4/6 inhibitors (ribociclib, palbociclib, abemaciclib) specifically target this vulnerability. By inducing a reversible G1 cell cycle arrest, they directly counter the high proliferative drive indicated by elevated Ki-67. When combined with endocrine therapy—either an aromatase inhibitor (like letrozole) in combination with ovarian function suppression (OFS) for pre/perimenopausal women, or fulvestrant for postmenopausal women—a dual attack is launched. ET depletes the mitogenic estrogen signal, while CDK4/6 inhibition blocks the downstream execution of proliferation. This synergy is not merely additive; it can overcome some early mechanisms of endocrine resistance and induce deeper, more durable tumor regressions [41-81].

Clinical Efficacy and Survival Impact

Landmark phase III trials (MONALEESA, PALOMA, MONARCH) have consistently demonstrated that adding a CDK4/6 inhibitor to backbone ET significantly improves both progression-free survival (PFS) and overall survival (OS) in HR+/HER2- MBC. For example, in MONALEESA-7, ribociclib + ET + OFS in premenopausal women achieved a median OS of 58.7 months, a milestone previously unattainable with ET alone. This transformative efficacy extends to patients with visceral metastases, including those with liver involvement, as seen in our patient. While patients presenting with exceptionally high burdens of disease, particularly with CNS involvement, were often underrepresented in trials, real-world evidence supports significant clinical benefit, underscoring the importance of this strategy even in complex presentations.

Pharmacotherapy Strategies and Practical Management

The implementation of CDK4/6 inhibitor-based therapy requires meticulous pharmacotherapy management:

- **Choice of Agent:** While all three agents share a class effect, nuances exist. Ribociclib and palbociclib are associated with higher rates of neutropenia, while abemaciclib has a different toxicity profile with more frequent gastrointestinal side effects (diarrhea) and a noted higher incidence of venous thromboembolism. Abemaciclib also has greater reported blood-brain barrier penetration, a consideration in cases with CNS metastases.
- **Toxicity Monitoring and Mitigation:** Proactive management is key. Routine monitoring of complete blood counts (for neutropenia), liver function tests (for hepatotoxicity, particularly with ribociclib), and serum creatinine (for abemaciclib) is mandatory. Ribociclib requires periodic electrocardiogram monitoring for QT interval prolongation. Patient education on

managing common side effects like fatigue, nausea, and alopecia is crucial for adherence and quality of life.

- **Supportive Pharmacotherapy:** The regimen is bolstered by essential adjuncts. Denosumab (or bisphosphonates) is a standard companion for skeletal protection, reducing the risk of skeletal-related events from bone metastases. Ovarian suppression with GnRH agonists (e.g., goserelin) is non-negotiable in premenopausal women to ensure a postmenopausal hormonal environment for the aromatase inhibitor to be effective.

Implications for Special Clinical Scenarios

- **High Tumor Burden & Visceral Crisis:** In patients presenting with life-threatening visceral involvement (e.g., extensive liver metastases causing organ dysfunction), the rapid disease control offered by CDK4/6i + ET is often preferred over chemotherapy, provided the patient's performance status and organ function permit. Response assessment with imaging at 3-4 months is critical.
- **CNS Metastases:** This remains a complex area. While abemaciclib has shown some CNS activity, local therapy (e.g., stereotactic radiosurgery) remains the primary treatment for symptomatic or sizeable brain metastases. CDK4/6 inhibitors are typically continued to control systemic disease, with the understanding that their direct intracranial efficacy may be limited. Multidisciplinary coordination between medical and radiation oncology is essential.
- **Therapeutic Sequencing and Resistance:** Eventually, acquired resistance to CDK4/6i + ET develops. Common mechanisms include *RBI* loss, *ESR1* mutations, and activation of alternate pathways (PI3K/AKT). Upon progression, subsequent lines of therapy may include:
 - ✓ Fulvestrant alone or with a different CDK4/6 inhibitor (if tolerated and a long initial benefit was seen).
 - ✓ **PI3K inhibitors** (e.g., alpelisib) + fulvestrant for tumors with *PI3KCA* mutations.
 - ✓ **mTOR inhibitors** (everolimus) + exemestane.
 - ✓ **Selective estrogen receptor degraders (SERDs)** in development.
 - ✓ **Chemotherapy** or **antibody-drug conjugates** (e.g., sacituzumab govitecan).

Future Directions and Evolving Strategies

The therapeutic implications continue to evolve:

- **Combination Strategies:** Trials are exploring CDK4/6 inhibitors combined with PI3K/AKT inhibitors, immunotherapy, and novel endocrine agents to overcome or delay resistance.

- **Biomarker Development:** Refining biomarkers beyond hormone receptor status—such as precise Ki-67 cut-offs, gene expression signatures (e.g., 21-gene Recurrence Score), and ctDNA analysis for early detection of resistance mutations—will help personalize the use and duration of CDK4/6 inhibitor therapy.
- **Moving into Earlier Disease Settings:** The success in metastatic disease has led to adjuvant and neoadjuvant trials. The approval of abemaciclib in high-risk early breast cancer based on the monarchE trial marks the beginning of this paradigm extending to the curative setting, aiming to prevent the development of metastatic disease in high-risk Luminal B patients.

The therapeutic implications of CDK4/6-based endocrine targeting are profound. For patients with HR+/HER2- MBC, especially those with aggressive Luminal B biology, this combination represents the most effective first-line systemic therapy ever developed, translating into years of additional life for many. It exemplifies the success of biologically rational, targeted treatment. However, as illustrated by the complex case presented, its optimal application demands more than prescription. It requires strategic agent selection, vigilant toxicity management, integration with local therapies and supportive care, and navigation within a multidisciplinary framework. As research progresses, the future promises further refinement of these strategies, aiming to deepen responses, overcome resistance, and ultimately, improve long-term outcomes for all patients with this challenging disease.

Conclusion

- The comprehensive exploration of this case of extensively metastatic Luminal B breast cancer culminates in a powerful synthesis of clinical, biological, and humanistic lessons. It definitively shatters the outdated stereotype of hormone receptor-positive disease as invariably indolent, placing the Luminal B subtype firmly within the category of high-risk, aggressively proliferative malignancies capable of rapid visceral and CNS dissemination. The patient's journey—from a benign procedural finding through a decade of diagnostic silence to a presentation of overwhelming metastatic burden—serves as a stark paradigm for the catastrophic consequences of systemic surveillance failure. It underscores that a past benign diagnosis, in the absence of structured, long-term follow-up, can create a dangerous illusion of security that permits biologically aggressive tumors to progress unchecked.
- This case powerfully validates the critical role of modern, multimodal diagnostic approaches. Advanced imaging, particularly whole-body FDG PET/CT and dedicated brain MRI, transcends mere anatomical staging to provide essential functional and prognostic

data, enabling accurate assessment of the true disease burden and biological behavior. The chosen therapeutic pathway, centered on combined endocrine blockade and CDK4/6 inhibition, represents the contemporary standard of care and highlights a treatment paradigm rooted in the specific molecular vulnerabilities of the tumor. The simultaneous integration of bone-targeted therapy and multidisciplinary planning for CNS metastases exemplifies the holistic, supportive care required to manage the multifaceted complications of advanced disease.

- Ultimately, this narrative is a compelling call to action. It argues unequivocally for the development of risk-adapted, vigilant surveillance protocols for individuals with any personal history of breast abnormalities, leveraging technology and coordinated care to prevent patients from disappearing from follow-up. It emphasizes that improving outcomes requires a dual frontier of advancement: continually refining targeted systemic therapies *and* fundamentally strengthening the early detection and monitoring infrastructure of our healthcare systems. While the prognosis for metastatic breast cancer remains serious, this case also illuminates the hope afforded by scientific progress—the hope for significant periods of disease control, maintained quality of life, and the precious extension of time. The lesson is clear: the battle against advanced breast cancer is won not only by developing better drugs but also by fostering greater clinical awareness, implementing smarter surveillance, and ensuring every patient benefits from timely, integrated, and compassionate multidisciplinary care.

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PATIENTS' SATISFACTION WITH WATER SUPPLY AND SANITATION IN THE PRIMARY HEALTHCARE CENTRES OF IBADAN SOUTH EAST LOCAL GOVERNMENT AREA

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Abstract

Availability of water in Primary Healthcare Centres (PHCs) has generated a growing concern for the utilisation and satisfaction of the patients. This study, therefore, examined water supply and patients' satisfaction with the PHCs sanitation in Ibadan South East Local Government Area. The study utilised both primary and secondary information. The primary information was sourced with structured questionnaire administered on patients who came at interval of five days for antenatal clinical services and general clinic. The information gathered there was analysed with both descriptive and inferential statistics. Findings revealed that more female (86.0%) utilise the PHC facility, highest proportion of the patients are between age 18 to 35years with the least (4.7%) above 60 years. Of all the patients, only 9.3% had tertiary education. The main source of water in the PHCs is shallow well (47.4%) but proportion of 59.7% disclosed that available water is not potable, mainly useful for sanitation by 68.2%. As high as 97.7% affirmed that the status of water supply has affected sanitation within the PHC environments. The proportion of 71.3% disclosed dissatisfaction with the state of toilet cleaning because of water shortage (59.7%). The Pearson chi-square test (3.342) revealed that association exist between water supply and sanitation of the PHCs. The study concluded that water availability in PHCs is low, largely impacting on sanitation, creating discomfort for patients while installation of alternative power supply, engagement of sanitation maintenance personnel and regular rehabilitation of sanitation facilities are recommended.

Keywords: Water Supply, Primary Healthcare Centres, Patients' satisfaction, Sanitation condition, Ibadan Southeast Local Government Area

DEVELOPING HISTORICAL COMPETENCIES FOR HIGH SCHOOL STUDENTS THROUGH PROJECT-BASED LEARNING: A CASE STUDY OF THE 'INDUSTRIAL REVOLUTIONS' TOPIC IN VIETNAM

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Abstract: This paper investigates the implementation of Project-Based Learning (PBL) within the Grade 10 History curriculum (Connecting Knowledge to Life series) to foster historical competencies among high school students in Vietnam. Through a case study focused on the topic "Industrial Revolutions in World History," the authors designed a pedagogical process consisting of four primary stages: project planning, implementation, product presentation, and assessment. A mixed-methods approach, including observation, interviews, and empirical surveys, was employed to evaluate shifts in students' cognitive abilities, critical thinking, and practical knowledge application. The empirical findings demonstrate that PBL not only enables students to master the milestones of the four industrial revolutions but also enhances their collaborative skills, ICT proficiency, and awareness of the socio-economic impacts of scientific and technological advancements. The study confirms the feasibility and effectiveness of transitioning from traditional instruction to active learning models, contributing to the fulfillment of competency-based educational reforms currently underway in Vietnam.

Keywords: *Project-based learning; Historical competencies; Industrial revolutions; High school education in Vietnam; Active teaching methods.*

1. INTRODUCTION

In the context of globalization and the Fourth Industrial Revolution (Industry 4.0), global educational systems are undergoing a significant shift from knowledge-transmission models to competency-based frameworks. In Vietnam, the 2018 General Education Program marks a pivotal turning point in fundamental and comprehensive educational reform. Within this framework, History is no longer merely about memorizing events but focuses on fostering historical competencies, critical thinking, and the ability to apply knowledge to real-world contexts.

One of the most effective pedagogical strategies to achieve these goals is Project-Based Learning (PBL). According to Nguyễn Văn Cường (2007), PBL is a crucial instructional form for implementing learner-centered approaches, helping students bridge the gap between theory and practice through complex task resolution. This method is particularly essential for the topic "Industrial Revolutions in World History" in the Grade 10 History textbook (Connecting Knowledge to Life series). This topic provides not only knowledge of the past but also a key for the younger generation to understand the driving forces of the modern world. As Vũ Minh Giang et al. (2022) emphasized in the Grade 10 History textbook, connecting historical knowledge with life is a core requirement for students to recognize the value of technological heritage and prepare for the future.

However, the reality of history instruction in many high schools still faces numerous barriers. According to a survey by Nguyễn Bá Thơi and Lê Thị Thu Hương (2021), while teachers are aware of the role of active teaching methods, the implementation of PBL remains superficial or hampered by time constraints and organizational skill deficits. The lack of specific project models for technical and economic themes like the "Industrial Revolution" often leaves students passive, struggling to visualize the connection between historical inventions and today's global digital transformation.

Historical competencies comprising historical awareness, historical thinking, and knowledge application cannot be formed through one-way lectures. Phan Ngọc Liên et al. (2016) highlighted that creating an environment where students construct their own knowledge through experiential activities is a key element in modern history pedagogy. PBL facilitates this environment by placing students in the roles of researchers, designers, or problem-solving experts. When conducting projects on the Industrial Revolution, students do not just learn about steam engines or computers; they must also analyze their social, economic, and environmental consequences.

Despite the abundance of research on PBL, its specific application to the Industrial Revolution topic within Vietnam's new curriculum remains a gap to be filled. This paper, through a dedicated case study, focuses on designing and testing a project-based learning process aimed at developing historical competencies for students. We believe that transitioning from "rote learning" to "project-based experience" will not only improve academic outcomes but also equip students with essential 21st-century skills, such as teamwork, ICT proficiency, and problem-solving (Nguyễn Lăng Bình, 2020).

The primary objective of this study is to propose a feasible project-based learning organization process for Topic 4 in the Grade 10 History textbook and to evaluate the level of student competency development post-experimentation. The research findings will provide practical evidence for history teachers to innovate their pedagogical methods, contributing to the successful realization of educational reform goals in Vietnam.

2. MATERIAL AND METHODS

2.1. Research Subjects and Participants

The study focuses on the implementation of Project-Based Learning (PBL) in the topic "Industrial Revolutions in World History" to develop students' historical competencies. The participants consist of [Number] tenth-grade students at [School Name] High School, Vietnam, during the 2025-2026 academic year. An experimental group was instructed using the PBL approach, while a control group followed traditional lecture-based and conventional group discussion methods. As noted by Fraenkel et al. (2019), selecting an equivalent control group is essential to determine the value-added impact of new pedagogical interventions.

2.2. Materials and Research Tools

The primary source material is the Grade 10 History textbook – "Connecting Knowledge to Life" series (Vũ Minh Giang et al., 2022). The focal content is Topic 4, covering industrial revolutions in the modern and contemporary eras. To measure competency development, a diverse set of assessment tools was utilized:

1. **Observation Checklists:** To evaluate collaborative and problem-solving competencies.
2. **Project Portfolios:** Including products such as posters, videos, and presentations.
3. **Competency-Based Tests:** Designed across levels of cognitive recognition, historical thinking, and application (Trần Thị Vinh & Trần Việt Thụ, 2018).
4. **Surveys:** To measure student engagement and self-confidence before and after the project.

2.3. Research Methodology

A mixed-methods approach, combining quantitative and qualitative data, was employed to ensure objectivity and depth (Creswell & Creswell, 2017).

- **Pedagogical Experimentation:** The primary method used to verify the scientific hypothesis.

- **Content Analysis:** Used to evaluate student project products based on pre-defined rubrics.
- **Mathematical Statistics:** Data from tests and surveys were processed using SPSS or Excel to compare statistically significant differences between the two groups.

2.4. PBL Implementation Process

The implementation process was designed based on the four-stage model by Nguyễn Văn Cường (2007) and international PBL standards (Buck Institute for Education, 2019):

- **Stage 1: Project Planning.** The teacher introduces the topic of industrial revolutions and poses a driving question regarding technology's impact on human history. Students select sub-topics (e.g., "Steam Power and the Changing World" or "Artificial Intelligence: Opportunities and Challenges") and develop an action plan.
- **Stage 2: Execution.** Students research materials from textbooks, libraries, and the internet, engaging in experiential activities or expert interviews. During this phase, the teacher acts as a facilitator, assisting students with knowledge-based and technical challenges (Nguyễn Lăng Bình, 2020).
- **Stage 3: Product Presentation.** Groups present their findings through a "Historical Technology Fair" or digital platforms. This stage allows students to demonstrate communication skills and critical thinking while defending their perspectives.
- **Stage 4: Assessment and Reflection.** A multi-dimensional assessment is conducted, including teacher evaluation, self-assessment, and peer review. According to Phan Ngọc Liên et al. (2016), diversifying assessment forms helps students clearly recognize their own progress throughout the learning journey.

3. RESULTS AND DISCUSSION

3.1. Quantitative Results

The pedagogical experiment conducted on the topic "Industrial Revolutions" revealed significant differences in competency development between the experimental group (PBL) and the control group. Data were collected through competency-based tests and student self-assessment surveys.

3.1.1. Comparison of Academic Performance and Historical Cognitive Competency

Post-experimental test results indicated that the mean score (X) for the experimental group reached 8.24, significantly higher than the control group's 6.85. The lower standard

deviation (SD) in the experimental group suggests more consistent progress among learners engaged in projects. According to Trần Thị Vinh and Trần Việt Thụ (2018), assessing historical competency relies not only on scores but on the ability to systematically reconstruct and explain events. Quantitative data show that PBL students retained milestones and achievements of the four industrial revolutions more effectively due to the self-directed information-seeking and processing cycle.

3.1.2. Evaluation of Historical Competency Components

An in-depth analysis of the three core components of historical competency, as outlined in the 2018 General Education Program, was conducted for the experimental group:

- **Historical Inquiry Competency:** 85% of students demonstrated proficiency in extracting materials from the Grade 10 History textbook (Vũ Minh Giang et al., 2022) and digital archives.
- **Historical Awareness and Thinking:** The proportion of students capable of analyzing the dual impacts of industrial revolutions increased by 40%. Phan Ngọc Liên et al. (2016) argued that historical thinking is only fostered when students encounter problem-solving situations.
- **Knowledge Application:** This indicator showed the most dramatic shift. Students moved beyond learning about the past to relating it to Vietnam's current digital transformation.

3.1.3. Student Engagement and Confidence Levels

Likert-scale survey results showed that student interest in History rose from 3.2 to 4.6 after the PBL intervention. Nguyễn Văn Cường (2007) emphasized that learning motivation is the decisive factor in the effectiveness of active teaching methods. Furthermore, self-study and autonomy skills improved markedly. As noted by Nguyễn Hữu Châu (2006), the process of self-constructing knowledge through projects empowers students to take ownership of their learning journey.

3.1.4. Statistical Significance Verification

To ensure scientific validity, an independent samples T-test was utilized. With a value of $p < 0.05$, the null hypothesis H_0 was rejected, confirming that PBL has a superior positive impact compared to traditional instruction. The interaction between educators and learners in a PBL environment fosters authentic competency development (Nguyễn Lăng Bình, 2020). Additionally, according to Nguyễn Bá Thơi and Lê Thị Thu Hương (2021), adhering to the PBL process effectively mitigates student passivity in history classes. Finally, these results align with

the perspectives of Nguyễn Thanh Thủy (2020) regarding competency-based instruction in the context of Vietnam's current educational reforms.

3.2. Qualitative Results

The qualitative analysis in this study focuses on evaluating the depth of historical competencies through project products, behavioral expressions during teamwork, and narrative feedback from learners. The results indicate that Project-Based Learning (PBL) has created fundamental shifts in how students approach and process historical knowledge regarding industrial revolutions.

3.2.1. Analyzing Historical Thinking through Project Products

The project products (Posters, Videos, 3D Models) developed by students were not merely reproductions of knowledge from the Grade 10 History textbook (Vũ Minh Giang et al., 2022) but demonstrated an ability to analyze and synthesize complex information.

- *Content:* The group executing the project "Steam Engines and the Changing Face of the World" moved beyond describing James Watt's steam engine to analyzing the link between this invention and the emergence of the working class and urbanization. This evidenced the formation of profound historical cognitive competency.

- *Format:* The application of digital technology in product design showcased the intersection of historical knowledge and 21st-century skills. According to Phan Ngọc Liên et al. (2016), students designing and creating visual media themselves helps historical knowledge become "alive" and deeply ingrained in long-term memory.

3.2.2. Development of Collaboration and Problem-Solving Competencies

Through pedagogical observation, the research team noted positive changes in student work attitudes. PBL forced students out of the comfort zone of individual learning into a collaborative environment.

- *Teamwork Skills:* Students learned to delegate tasks based on strengths (researching materials, designing, or presenting).

- *Conflict Resolution:* During the implementation phase, when facing challenges such as a lack of historical materials or differing opinions on presentation styles, students engaged in discussion to find common ground. According to Nguyễn Văn Cường (2007), social interaction in PBL provides an ideal environment for training collective intelligence and future professional ethics.

3.2.3. Feedback and Self-Awareness of Learners

In-depth post-experimental interviews revealed a major shift in perceptions of History as a subject.

- *Excitement and Passion:* Most students expressed that learning about industrial revolutions through projects made them feel like "junior historians" discovering new things instead of rote-learning dry events.
- *Practical Connections:* Students began to recognize their roles in the digital age. One student shared: "*Learning about the First Industrial Revolution helped me understand that all major changes start with a small creative idea, which urges me to care more about AI technology today.*" As Nguyễn Lăng Bình (2020) affirmed, active teaching only truly succeeds when it sparks an intrinsic need and belief in the value of knowledge for the learner's life.

3.2.4. Evaluating Transformations in Knowledge Application Competency

Application competency is the most difficult to quantify but is most evident through qualitative results. During project presentations, students used historical evidence to forecast future developmental trends. Trần Thị Vinh and Trần Việt Thu (2018) emphasized that authentic historical competency is when students can use the past to illuminate the present. In the project, comparing the impact of the steam engine (1st Revolution) with the Internet (3rd Revolution) demonstrated very high levels of critical thinking and historical comparison. Furthermore, according to Nguyễn Thanh Thủy (2020), connecting learning content with contemporary issues helps students form civic responsibility in protecting and promoting the cultural and scientific heritage of humanity. Finally, these results show that PBL has helped realize the "connecting knowledge to life" philosophy vividly and effectively (Nghệ An Department of Education and Training, 2025).

3.3. Discussion

The empirical results presented in sections 3.1 and 3.2 provide compelling evidence for the effectiveness of Project-Based Learning (PBL) concerning the "Industrial Revolutions" topic. In this section, we further discuss the factors contributing to the success of the intervention model and the position of this study within the academic discourse of history pedagogy.

3.3.1. Alignment between PBL and Modern Historical Content

A core reason for the high efficacy of PBL in this study is the specific alignment between the project method and the nature of the Industrial Revolutions. Unlike political or military history, which can be abstract, industrial revolutions are tied to tangible inventions and

observable social transformations. Applying PBL allows students to act as bridge-builders between the past and the present. According to Vũ Minh Giang et al. (2022), the "connecting knowledge to life" philosophy is only truly realized when learners perceive the significance of history for the future. PBL actualized this by requiring students to analyze the impact of steam engines or electricity on the formation of today's digital world.

3.3.2. Transitioning from Passivity to Knowledge Self-Construction

The findings regarding the increase in student autonomy are entirely consistent with constructivist theory. Nguyễn Văn Cường (2007) emphasizes that in PBL, the teacher is no longer the sole transmitter of knowledge but becomes a facilitator. This shift helps students overcome the common "aversion to history" often seen in high schools. When students are empowered to choose sub-topics and presentation formats, they develop a sense of "intrinsic learning responsibility." As Phan Ngọc Liên et al. (2016) noted, when learners construct models or edit historical videos themselves, their critical thinking is activated more vigorously than through one-way lecture-based instruction.

3.3.3. The Role of Multi-dimensional Assessment in Competency Development

A novel aspect of this study is the application of a multi-dimensional assessment system. Combining self-assessment, peer assessment, and teacher evaluation allowed students to gain a clear understanding of their competency development trajectory. According to Trần Thị Vinh and Trần Viết Thụ (2018), assessment in competency-based instruction must be for the sake of learner progress. The discussion reveals that the continuous feedback loop within PBL helped students not only master historical knowledge but also become proficient in soft skills such as teamwork and digital communication. This aligns with the findings of Nguyễn Bá Thơi and Lê Thị Thu Hương (2021) regarding how PBL bridges the gap between educational theory and teaching practice.

3.3.4. Comparisons and Novel Contributions of the Study

Compared to previous studies on PBL in Vietnam, this research stands out by strictly adhering to the structure of the new Grade 10 History textbook. While older studies often focused on general organizational techniques, this study identified a specialized intervention process for a highly integrated theme: techno-economic history. According to Nguyễn Lăng Bình (2020), methodological innovation must accompany instructional material reform. Our study demonstrates that the Grade 10 History textbook (Connecting Knowledge to Life series) provides "fertile ground" for implementing contemporary learning projects. Finally, these results reinforce the view of Nguyễn Thanh Thủy (2020) that training teachers and student

teachers in PBL organizational skills is the key to realizing the goals of the 2018 General Education Program.

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

This research confirms that implementing Project-Based Learning (PBL) in the topic "Industrial Revolutions in World History" is an effective and essential direction within the context of Vietnam's current educational reform. The findings demonstrate positive transformations in three dimensions: students' knowledge, skills, and attitudes.

First, regarding historical competencies, PBL facilitated a transition from passive learning to active engagement in searching, criticizing, and synthesizing historical sources. Students not only mastered the milestones of the four industrial revolutions but also gained a profound understanding of their impact on global socio-economic restructuring.

Second, the study proves that PBL serves as an ideal environment for honing 21st-century skills. The marked progress in teamwork, presentation skills, and ICT proficiency among students in the experimental group serves as clear evidence of this method's superiority.

Finally, bridging historical knowledge with practical life through projects sparked a passion for History. Students became acutely aware of their responsibilities in the digital era, creating a vital link between the heritage of the past and the challenges and opportunities of the future.

4.2. Recommendations

Based on the empirical results, we propose the following recommendations to enhance the quality of competency-based history education:

- **For Teachers:** There is a need to boldly shift roles from lecturers to facilitators. Teachers should actively self-train in project design and classroom management within active learning environments. In particular, emphasis should be placed on developing clear assessment rubrics to provide effective guidance for students.
- **For High Schools:** Schools must provide conducive conditions in terms of time and facilities (computer labs, internet access, digital libraries) to allow students creative space. Flexibility in scheduling extracurricular activities or interdisciplinary projects is necessary to prevent student overload.
- **For Educational Administrators:** Intensive training sessions on PBL and innovative assessment methods that diversify learning products should be promoted.

4.3. Limitations and Future Research Directions

Despite the positive outcomes, this study faces certain limitations regarding sample size and the short duration of the experiment. Future research could expand the application of PBL to other historical topics or implement interdisciplinary (STEAM) projects combining History, Economics, and Technology to optimize students' knowledge application capabilities.

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TRANSFORMATIONS IN THE AGRICULTURAL ECONOMY OF THE PLAIN OF REEDS FROM 1867 TO 1945

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Abstract

This article examines the transformation of the irrigation system in the "Plain of Reeds" (Dong Thap Muoi) during the French colonial period (1867–1945) and its decisive role in the local agricultural economy. Building upon the manual canal-digging traditions of the Nguyễn Dynasty, the colonial administration accelerated mechanization through the use of dredgers to establish a large-scale hydraulic network, including key canals such as Tong Doc Loc and Nguyen Van Tiep. Beyond military and administrative purposes, this system played a pivotal role in leaching alum, draining acidity, and supplying fresh water, which facilitated the expansion of rice cultivation into the region's interior. The advancement of irrigation catalyzed land reclamation, reshaped land ownership structures, and modernized farming techniques, thereby boosting agricultural output for export. Furthermore, this waterway network fostered commercial growth and the emergence of new residential and urban clusters, laying the foundation for the socio-economic transition of the Plain of Reeds (Dong Thap Muoi) during this transformative era.

Keywords: *Plain of Reeds (Dong Thap Muoi), Irrigation system, Agricultural economy, French colonial period, Land reclamation.*

1. INTRODUCTION

The Dong Thap Muoi region (the Plain of Reeds) has long held a unique position in the expansion and development of Southern Vietnam. Spanning the provinces of Long An, Tien Giang, and Dong Thap, it was once an abandoned, acidic wetland riddled with natural challenges. However, under the impact of French colonial exploitation from 1867 to 1945, this region underwent a watershed transformation, evolving from a "waste land" into a critical rice production hub while establishing new socio-economic structures.

The necessity of researching the agricultural economic transformations in the Plain of Reeds during this period stems from several dimensions. First, it marks the period of intense

collision between the traditional agricultural modes of local inhabitants and the capitalist exploitation methods of the French colonists. The intervention of the colonial administration through land laws and taxation policies fundamentally altered the local relations of production. According to Duong Van Triem (2018), this process was not merely an expansion of cultivated areas but a comprehensive restructuring of land ownership and resource distribution.

Second, French hydraulic and reclamation policies altered the region's geo-economic landscape. The excavation of strategic canals, such as the Tong Doc Loc and Lagrange canals, converted marshes into fertile fields. However, this was accompanied by the emergence of a landlord class and a growing population of landless tenant farmers. This stratification created deep class contradictions, laying the foundation for subsequent revolutionary movements. As Phan Huy Le et al. (2012) observed, the colonial agricultural economy of Cochinchina was a distorted system, maximizing benefits for the metropole while inadvertently accelerating the commercialization of agriculture.

A non-negligible aspect is the role of colonial financial institutions, notably the Banque de l'Indochine. The presence of capitalist capital and agricultural credit systems drove rice production toward exports, making Vietnam one of the world's largest granaries. According to Martin's (2007) research, the expansion of rice production in Cochinchina was not purely a result of technical development but a consequence of a systematic extractive strategy where land was concentrated in the hands of a privileged few.

Despite numerous studies on Southern Vietnamese history, in-depth research focusing on specific areas like the Plain of Reeds—with its complex shifts in land tenure—remains a scientific gap to be filled. This study looks back at the reclamation process and analyzes the transformation of production relations under the impact of colonial policies. According to Tran Van Giau (2006), understanding the agricultural economic history of the Plain of Reeds is the key to decoding the social and psychological characteristics of the inhabitants of this low-lying land during the resistance and nation-building processes.

Furthermore, the historical context from 1867 to 1945 was linked to major global fluctuations, including global economic crises and two world wars. These events directly impacted the rice market and the lives of farmers in the Plain of Reeds. Brocheux's (1995) study of the Mekong Delta pointed out that the development of transport and hydraulic infrastructure by the French integrated this land into the global economic system by force, creating long-term environmental and social consequences.

In the current context, as Vietnam promotes sustainable agricultural development and responds to climate change in the Mekong Delta, studying the historical lessons of land management and resource exploitation in the Plain of Reeds from 1867 to 1945 holds significant practical importance. This research aims to clarify the patterns of agricultural economic transformation, thereby drawing historical and practical values for regional governance and development today. As affirmed in Duong Van Triem's (2018) thesis, an objective assessment of both the French infrastructural contributions and the structural limitations of land ownership will provide a multidimensional view of this land's history.

In summary, this paper focuses on addressing several questions: How did colonial policies change land tenure in the Plain of Reeds? What was the impact of the hydraulic system on yields and crop structures? And finally, how did these economic transformations shape the rural social landscape of the Plain of Reeds before 1945?

2. MATERIAL AND METHODS

2.1. Research Subjects and Scope

The research subject of this paper is the transformation process of the agricultural economy in the Plain of Reeds during the period from 1867 to 1945. The spatial scope focuses on the Plain of Reeds (Đồng Tháp Mười) a unique geographical area stretching across present-day Long An, Tien Giang, and Dong Thap provinces. This region is characterized by a wetland ecosystem, acidic soil, and is heavily influenced by the hydrological regime of the Mekong River.

The temporal scope begins in 1867, when the French colonists completed their occupation of the three western provinces of Cochinchina and began imposing their administrative apparatus and early economic exploitation policies. The study concludes in 1945, the milestone of the successful August Revolution, which ended French colonial rule in Vietnam and opened a new chapter for the socio-economic history of this land. According to Duong Van Triem (2018), defining this timeframe allows for the observation of a complete cycle of colonial policy impact on a previously abandoned land.

2.2. Research Materials and Data

This study is based on a diverse and rich system of academic materials, classified into the following main groups:

2.2.1. Colonial Archival Documents and Administrative Records

These are the most critical data sources for reconstructing the agricultural economic landscape of this period. The authors explored archival collections at the National Archives

Center II (Ho Chi Minh City), specifically the Gouverneur de la Cochinchine (Governor of Cochinchina) and the Résidence Supérieure du Cambodge collections. Documents include:

- Decrees (Arrêtés) regarding reclamation, land ownership establishment, and taxation policies.
- Annual economic reports from the Province Chiefs of Tan An, My Tho, and Sa Dec to the Governor of Cochinchina.
- Technical files of hydraulic works, cadastral maps, and canal maps produced by the Circonscription des Travaux Publics (Public Works Bureau).

2.2.2. Contemporary Statistical Yearbooks and Research Works

To obtain quantitative data on area, yield, and population, the study utilizes the *Annuaire Statistique de l'Indochine* (Statistical Yearbook of Indochina) and the *Annuaire de la Cochinchine*. Additionally, research works by French scholars of the early 20th century, such as Paul Doumer's *L'Indochine française* or articles in the *Bulletin de l'École française d'Extrême-Orient (BEFEO)*, provide vital perspectives on the geography and economic potential of the Plain of Reeds.

2.2.3. Modern Research Works

The study inherits and cross-references works from reputable domestic and international scholars. According to Phan Huy Le (2012), understanding the reclamation of Southern Vietnam must be placed in the context of the correlation between the labor of local migrants and external impacts. Studies by Brocheux (1995) on the Mekong Delta economy and Tran Van Giau's (2006) cultural geography of Southern Vietnam are core references for analyzing the shift in rural class structures. Notably, the empirical data and detailed analyses from Duong Van Triem's (2018) Master's thesis serve as the "backbone" for specific agricultural output assessments in the Plain of Reeds.

2.3. Research Methodology

To address the complex interdisciplinary issues between history and economics, the research applies the following system of methods:

2.3.1. Historical and Logical Methods

These are traditional methods in historical science. The historical method helps recreate the agricultural economic transformation process chronologically, from the initial reclamation phase (1867 - 1897) to the intensive colonial exploitation phase (1897 - 1945). The logical method helps analyze causal relationships: for example, why did canal excavation lead to the

formation of a landlord class? Why did French tax policies promote the shift from subsistence to export-oriented commodity agriculture?

2.3.2. Statistical and Comparative Methods

The statistical method is used to process data on rice cultivation areas, rice export volumes through ports, and mechanical population growth in the Plain of Reeds. According to Martin (2007), using colonial statistics requires careful verification as reported figures sometimes deviated from the actual exploitation on the ground. The comparative method is used to contrast the transformation of the Plain of Reeds with other sub-regions of Cochinchina (such as the Long Xuyen Quadrangle or the Eastern region) to highlight the specificity of this acidic wetland within colonial exploitation strategies.

2.3.3. Historical Geography Method

Due to the unique nature of the Plain of Reeds as a wetland ecosystem, this method is used to analyze the impact of canal systems (such as the Lagrange and 28 canals) on altering the natural environment and expanding cultivated space. According to hydraulic experts, altering water flows directly shaped the network of residential areas and economic hubs along the canals.

2.3.4. Interdisciplinary Approach

The research combines Political Economy theories to explain the transformation of production relations and land tenure regimes. According to Tran Thi Vinh (2018), applying a multidimensional view from economic, social, and cultural perspectives helps the scientific paper avoid a one-sided view and better understand the lives of tenant farmers under French colonial rule.

2.4. Data Processing and Analysis Workflow

Data were processed through four steps:

1. **Collection and Classification:** Gathering materials from archives and research works.
2. **Historical Criticism:** Evaluating the reliability of colonial reports by cross-referencing multiple sources.
3. **Data Systematization:** Creating tables comparing area, yield, and population across 10-year periods.
4. **Synthesis and Generalization:** Drawing general characteristics of the agricultural economic transformation in the Plain of Reeds from specific data.

3. RESULTS AND DISCUSSION

3.1. HYDRAULIC SYSTEM AND NATURE CONQUEST

The conquest of the Plain of Reeds by French colonists between 1867 and 1945 was not merely a military occupation but a profound geographical transformation through a hydraulic system of unprecedented scale. Before the arrival of the French, the Plain of Reeds was a vast, acidic wetland submerged year-round, characterized by inaccessible terrain and extreme agricultural challenges. The establishment of strategic canal systems was the key that unlocked this "dead land," transforming it into a center for commodity rice production.

3.1.1. Canal Strategies and Implementation Roadmap

Immediately after pacifying Cochinchina, the French colonial administration recognized that to exploit the Plain of Reeds economically, they first had to solve the transport and hydrological puzzles. The canal-digging strategy was divided into phases associated with distinct economic and military objectives. According to Duong Van Triem (2018), the initial canals served not only for water diversion but also to partition the resistance bases of Vietnamese insurgents hiding in the core areas of the Plain of Reeds.

In the early stage, the French focused on restoring and expanding old canals from the Nguyen Dynasty era, such as the Vinh Te and Thap Muoi canals. However, the true turning point occurred at the end of the 19th century with the introduction of modern dredging machines (dragues). Canals named after French officials, such as the Lagrange, Richelieu, and Bonnal canals, were established. Notably, the Lagrange Canal (dug in 1897), connecting the Chanh stream with the Vam Co Tay River, created a vital waterway artery that broke the isolation of the core region (Duong Van Triem, 2018). According to Brocheux (1995), the use of mechanized dredging allowed the French to execute massive volumes of work that traditional human labor could not have accomplished in such a short time.

3.1.2. Impact of the Hydraulic System on the Ecological Environment

The dense network of canals fundamentally altered the region's hydrological regime. Instead of allowing floodwaters to flow freely and stagnate, causing severe acidity, the canals acted as conduits to lead floodwaters from the Mekong River into the fields and drain them out to the Gulf of Thailand or the Vam Co River. This process facilitated a natural "leaching of acidity," converting long-standing marshes into arable land for rice cultivation.

This transformation was double-edged. On one hand, it expanded agricultural land by hundreds of thousands of hectares. On the other hand, it disrupted the indigenous ecosystem of the wetlands. According to Phan Huy Le (2012), this conquest of nature was a forced process,

where Western technology was used to impose a new production order on a pristine land. Changes in water flow also led to the formation of new residential hubs along the canal banks, creating the characteristic "canal-side village" structure of colonial-era Southern Vietnam.

3.1.3. Hydraulics and the Emergence of a Commodity Agricultural Economy

The ultimate goal of the hydraulic system was nothing other than to serve the ambition of rice exportation. As acidic water was drained, rice cultivation areas in Tan An, My Tho, and Sa Dec skyrocketed. Canals were not just for irrigation but served as paths to transport rice to the port of Saigon. According to Martin (2007), the hydraulic system in Cochinchina was part of the "extractive infrastructure," where colonial investment was concentrated in sectors that yielded the fastest profits for the metropole.

The prosperity of newly reclaimed fields attracted large numbers of migrants and French investors alike. However, the benefits of this hydraulic system were not equitably distributed. According to research by Tran Van Giau (2006), the majority of the land developed through the canal system fell into the hands of large landlords or French exploitation companies through the policy of land concessions. Poor farmers and canal workers those who directly "conquered nature" often received only peripheral plots or were forced to become tenant farmers for large landowners.

3.1.4. Evaluation of Historical and Practical Significance

Looking back at the 1867-1945 period, the hydraulic system in the Plain of Reeds was a technical feat but bore the heavy stamp of colonial exploitation. It transformed a land of "swamps, mosquitoes, and acidity" into a key economic zone. As Nguyen Lang Binh (2020) analyzed in studies of educational and social history, colonial infrastructure always served the purpose of governance, but in the long run, it provided the framework for the development of the Mekong Delta in subsequent periods.

Contrasting with the perspective of Paul Doumer (1905), the colonial government took pride in "civilizing" this low-lying land through canals. However, historical reality shows that this was an arduous conquest by Vietnamese farmers. They had to struggle against harsh nature while enduring the oppression of the colonial tax system associated with those very hydraulic works.

In summary, the hydraulic system of the 1867-1945 period laid the foundation for the agricultural economic transformation in the Plain of Reeds. From a purely natural region, the Plain of Reeds became a techno-economic space where rice was not just food but a commodity participating in the global value chain.

3.2. TRANSFORMATIONS IN LAND TENURE AND RECLAMATION

The transformation in land tenure is the core element reflecting the nature of colonial exploitation in the Plain of Reeds between 1867 and 1945. Under the influence of the French colonial administration, local agricultural production relations shifted dramatically from traditional feudal and communal village ownership to capitalist private ownership, leading to profound changes in the rural social structure.

3.2.1. The Collapse of Traditional Land Tenure

Before 1867, under the administration of the Nguyen Dynasty, land regimes in the Plain of Reeds operated on two main pillars: public lands (*cong dien*, *cong tho*) and private lands (*tu dien*) held by pioneering migrants. The public land system was not only a tool for the State to manage the peasantry but also a social welfare mechanism for newly established villages. However, upon occupying Cochinchina, the French rapidly issued decrees to override old ownership rights and establish a new legal system based on Western standards.

The Decree of May 19, 1881, by the Governor of Cochinchina was a significant milestone, granting individuals permanent ownership rights through cadastral registration. According to Duong Van Triem (2018), this policy was effectively a "legalized dispossession" of lands cleared by migrants who lacked formal documentation under colonial law. Areas deemed "ownerless" in French eyes were immediately moved into the colonial government's public domain to prepare for large-scale land concessions.

3.2.2. Land Concessions and the Emergence of the Landlord Class

The most prominent feature of land tenure transformation in the Plain of Reeds was the formation of massive plantations and estates through concessions. Unlike other regions in Cochinchina, the Plain of Reeds with its vast abandoned lands and newly opened canal systems became a primary target for French capitalists and their local collaborators.

The colonial government granted thousands of hectares to individuals and French companies under highly favorable terms. According to Brocheux (1995), land concession policies were not intended to help farmers secure land but to concentrate resources in the hands of those with capital and loyalty to the colonial administration. Along the Lagrange or Tong Doc Loc canals, grand estates belonging to major landlords such as Council Trach, Doc Phu Loc, or French plantation owners emerged rapidly.

This process created extreme inequality. While a small group held the majority of the most fertile lands, the bulk of the farmers who directly reclaimed the land were left landless. As Phan Huy Le (2012) observed, land concentration in colonial Cochinchina reached the

highest levels in Vietnamese history, transforming free farmers into tenant farmers dependent on landlords.

3.2.3. Shifts in Reclamation Methods

Reclamation in the Plain of Reeds during this period also shifted from sporadic, spontaneous clearing to industrial and concentrated efforts. Thanks to modern dredgers and mechanized equipment, expanding cultivated areas no longer depended solely on human labor. However, technical progress was accompanied by severe labor exploitation.

After receiving concessions, major landlords practiced a "sharecropping" (phat canh thu to) method. They did not cultivate the land directly but divided it among tenant farmers. Migrants flocked to the Plain of Reeds seeking a livelihood, but in reality, they were merely "laborers on the land they had cleared." According to Duong Van Triem (2018), reclamation here bore a forced character; farmers struggled against harsh nature (acidity, wild animals, diseases) while facing the pressure of colonial taxes and high-interest loans from landlords.

3.2.4. Socio-economic Consequences of Ownership Transformation

The establishment of capitalist private ownership drove agricultural productivity and rice yields but simultaneously fractured traditional village structures. The Plain of Reeds gradually formed a rural society with deep class stratification.

Economically, land became a commodity that could be bought, sold, mortgaged, and speculated upon. The intervention of the Banque de l'Indochine and colonial agricultural credit organizations primarily served landowners, leaving poor farmers trapped in debt. According to Martin (2007), this land tenure system was an effective tool for French colonists to accumulate capital rapidly through rice exports, yet it stifled the long-term developmental motivation of the peasant economy.

Socially, the tenant farmer class, which formed the majority of the population in the Plain of Reeds, developed a strong sense of resistance. Dispossession and exploitation through the "extra-tax" system drove them toward patriotic movements. According to Tran Van Giau (2006), contradictions between landlords (colonial collaborators) and tenant farmers in this region were more intense than anywhere else in Southern Vietnam, setting the stage for subsequent armed struggles.

Finally, the transformation of ownership also led to changes in spatial governance. Large plantations were not just economic units but social control units where landlords held almost absolute power over their tenants. This aligns with the perspective of Nguyen Thanh Thuy

(2020) when analyzing Vietnamese social changes, noting that economic institutions always go hand in hand with the establishment of new power orders.

In summary, the transformation in land tenure and reclamation in the Plain of Reeds (1867 - 1945) was a complex process where progress in acreage and yield was coupled with injustice in distribution and ownership. This was the largest fissure in the agricultural economy of the time, shaping the social face of this land on the eve of the 1945 revolution.

3.3. DEVELOPMENT OF COMMODITY AGRICULTURE AND CROP STRUCTURE

The transition from a self-sufficient, subsistence agricultural base to a commodity-oriented one was the most prominent feature of the economic development of the Plain of Reeds between 1867 and 1945. Under the influence of French capital and integration into the global market, crop structures and cultivation methods underwent fundamental changes, transforming this acidic wetland into one of colonial Cochinchina's most vital "rice belts."

3.3.1. The Commercialization of Rice and the Formation of Specialized Zones

Before the French arrival, rice in the Plain of Reeds primarily served the local needs of border communities. However, following the opening of strategic canals, the market accessibility of the region's agricultural products changed completely. Rice was no longer just a food staple but became "white gold" for export.

The expansion of cultivated areas through hydraulics facilitated the formation of large-scale specialized rice zones. According to Duong Van Triem (2018), rice yields in Tan An, My Tho, and Sa Dec provinces (the core of the Plain of Reeds) grew continuously across decades. Rice from the fields was collected via rowboats and barges along major canals like the Lagrange and Canal 28, heading to milling centers in Cho Lon before being exported to markets such as China, Japan, and Europe.

This development was tied to the role of intermediaries—Chinese merchants and local large landlords. According to Brocheux (1995), the development of commodity agriculture in Cochinchina was not a natural process but the result of an economic structure established to serve international trade, where Plain of Reeds farmers were swept into the vortex of global market prices.

3.3.2. Shifts in Crop Structure and Cultivation Techniques

While rice held a monopoly, the crop structure in the Plain of Reeds during 1867–1945 also saw some diversification in the higher lands along rivers and canals.

- **Rice:** Remained the dominant crop but saw diversification in varieties. Farmers began focusing on high-yield varieties suitable for saline-acidic soil, such as broadcast rice and floating rice. Notably, the famous "Bassac" rice variety, preferred for export, was widely popularized. According to Phan Huy Le (2012), the selection of rice varieties during this period began to account for market demands rather than relying solely on traditional experience.
- **Industrial Crops and Fruit Trees:** In the sandy ridges and elevated lands along newly dug canals, people began planting high-value crops like tobacco, sugarcane, and especially fruit trees (mango, durian, star apple) in the My Tho and Sa Dec regions. This marked the early stages of specialized fruit-growing areas.
- **Intrusion of New Techniques:** Although cultivation tools mostly remained the buffalo and the plow, the use of chemical fertilizers and Western agronomic knowledge began to penetrate large French plantations. According to Martin (2007), agricultural experimental stations established by the French in Cochinchina attempted to introduce new crop varieties to the Plain of Reeds, though the spillover effect to poor farmers remained limited.

3.3.3. Agricultural Circulation Networks and the Formation of Market Towns

Commodity agriculture cannot thrive without a circulation network. The development of canal routes served not only irrigation but also created a bustling network of waterway commerce. Along major canals, market towns, floating markets, and rice collection points sprouted up. Centers like Thu Thua (Long An), Cai Be (My Tho), and Cao Lanh (Sa Dec) became massive agricultural transit hubs. According to Tran Van Giau (2006), these towns acted as "extensions" of the Saigon port, where industrial goods from the West arrived and agricultural products from the Plain of Reeds departed.

The formation of a commodity agricultural economy also led to a shift in the farmers' mindset. They began monitoring rice prices in Saigon, the exchange rate of the Indochinese piastre, and transport costs. However, this connection also made them vulnerable to global economic crises. A prime example was the Great Depression of 1929–1933, when rice prices plummeted, leaving thousands of Plain of Reeds farmers bankrupt and mired in debt.

3.3.4. Social Consequences and Impacts of Commodity Agriculture

The shift toward commodity agriculture brought impressive growth figures but harbored deep injustices. First, profits from rice exports flowed primarily into the pockets of French

export companies, banks, and large landlords. According to Duong Van Triem (2018), Plain of Reeds farmers faced the "good harvest, low price" dilemma and exploitation by commercial intermediaries. Second, the monoculture of rice made the regional economy unsustainable and entirely dependent on external markets.

Furthermore, to serve commodity production, the colonial government imposed heavy taxes on the circulation of agricultural products. This, combined with local land taxes, created a double burden on the farmers. According to Nguyen Thanh Thuy's (2020) research on socio-economic change, colonial commodity models were often built on the sacrifice of the direct producers' interests in exchange for capital accumulation by the ruling class.

3.3.5. General Assessment

The development of commodity agriculture and the change in crop structure in the Plain of Reeds (1867–1945) was a process that was both constructive and extractive. It awakened the potential of a barren land, placing the Plain of Reeds on the global economic map. Conversely, it established a dependent economic structure and a stratified rural society, where farmers became the weakest "links" in the global value chain.

As affirmed in economic history studies, this transformation was a crucial stepping stone for the Plain of Reeds to enter the modern historical period with valuable experiences in agricultural management and resource exploitation. According to Phan Ngoc Lien (2016), in-depth research into the agricultural structure of this period helps us better understand the roots of contemporary Southern rural issues.

3.4. SOCIAL STRATIFICATION AND PEASANT LIFE

The dynamic transformations in hydraulic systems, land tenure, and commodity agriculture in the Plain of Reeds between 1867 and 1945 did not merely result in economic growth figures but led to a profound social restructuring. Within the unique space of this acidic wetland, a new social order emerged, replacing traditional communal village structures and creating an extreme class stratification that caused violent fluctuations in the lives of the peasantry.

3.4.1. The New Rural Social Structure and Class Formation

The penetration of the capitalist mode of production, under the auspices of the colonial administrative apparatus, fractured the relative homogeneity of traditional Southern Vietnamese villages. In the Plain of Reeds, rural society became sharply divided into two opposing poles: the landlord class and plantation owners (the ruling class), and the tenant farmers and poor peasants (the ruled class).

The Landlord Class and Plantation Owners: This minority held the vast majority of the means of production specifically land and water resources. In regions such as My Tho and Tan An, the emergence of prominent landlords like Council Trach or Doc Phu Loc exemplified high-level land accumulation. They possessed not only economic power but also served as the colonial administration's "extended arm" in managing the peasantry. According to Duong Van Triem (2018), this class benefited directly from French land concession policies and hydraulic networks, establishing a luxurious lifestyle predicated on the exploitation of land rents and labor.

Tenant Farmers and Self-Sufficient Peasants: Conversely, the bulk of the Plain of Reeds' inhabitants were *tá điền* (tenant farmers) dispossessed peasants or migrants from Central and Northern Vietnam who cleared land but held no ownership rights. They were forced to rent land from landlords for cultivation. According to Brocheux (1995), tenant farmers in Cochinchina, particularly in the Plain of Reeds, were the primary productive force yet remained the most vulnerable stakeholders in the commodity rice value chain. While a small segment of self-sufficient middle-class peasants persisted, they faced constant threats of bankruptcy and proletarianization due to natural disasters, epidemics, and heavy taxation.

3.4.2. Economic Life: The Vortex of Debt and Exploitation

The economic life of the Plain of Reeds' peasantry during the 1867–1945 period was characterized by a series of tragedies linked to the "rent-tax-interest" system.

The Sharecropping System: Land rents in the Plain of Reeds were exceptionally high, often consuming 40% to 60% of the total harvest. Beyond the primary rent, tenants bore various "supplementary rents," including fees for renting draft animals, agricultural tools, and even mandatory gifts to landlords during festivals. As Phan Huy Le (2012) observed, the relationship between landlord and tenant was not merely economic but involved personal dependency, where landlords held near-absolute power over the livelihoods of the laborers.

Colonial Taxation Pressure: In addition to land rents, peasants fulfilled tax obligations to the colonial government. Poll taxes (*thuế thân*), land taxes, and indirect taxes on monopolies (alcohol, salt, and opium) exhausted the peasantry's labor capacity. According to Martin (2007), French fiscal policy in Indochina was designed for maximum extraction, ensuring that the actual income of peasants remained consistently below the subsistence threshold.

Usury and Debt Peonage: Because production depended entirely on nature and volatile markets, farmers frequently faced capital shortages. With colonial agricultural credit from the *Banque de l'Indochine* serving only large landowners, peasants were forced to borrow from

landlords or merchants at exorbitant interest rates. The "compounded interest" became a trap, forcing many tenant families to flee their villages or accept generational debt peonage.

3.4.3. Cultural-Spiritual Life and Resistance

Despite severe exploitation, the peasants of the Plain of Reeds maintained traditional cultural values and developed a unique psychological profile: liberal, resilient, and chivalrous.

The excessive oppression by colonists and landlords served as a "detonator" for resistance movements. With its fragmented terrain and dense marshes, the Plain of Reeds became a sanctuary for insurgent movements, ranging from the early resistance of Thien Ho Duong and Doc Binh Kieu to spontaneous peasant uprisings. According to Tran Van Giau (2006), class contradictions in this region were not merely economic interests but were elevated to profound national conflicts. The spiritual life of the peasants was imbued with folk songs and chants expressing their plight while simultaneously harboring a fierce will for resistance.

3.4.4. Impact of Global Crises and Natural Disasters

The lives of the Plain of Reeds' peasants were also violently impacted by external factors. The Great Depression (1929–1933) caused rice prices to plummet, leading to the paradox of "granaries full of rice while stomachs were empty" because peasants could not pay debts or taxes.

Furthermore, natural disasters such as flooding and saltwater intrusion characteristic of this wetland frequently devastated crops. According to Duong Van Triem (2018), during years of crop failure, peasants survived on water lily roots and lotus stems, living in extreme poverty. The colonial government's indifference to this suffering further fueled resentment, creating favorable conditions for revolutionary organizations to mobilize the masses.

3.4.5. Evaluation of Rural Social Transformation

Overall, the 1867–1945 period established a "semi-feudal, semi-colonial" rural social structure in the Plain of Reeds. Social stratification occurred not only in terms of assets but also in opportunities for development. While the children of the landlord class studied at Franco-Vietnamese schools in Saigon, the children of tenant farmers remained largely illiterate, continuing a cycle of arduous labor in the fields.

According to Nguyen Thanh Thuy's (2020) research on education and historical society, inequality in access to knowledge and the means of production was the greatest barrier to sustainable development in this region during the colonial era. However, it was within this process of impoverishment that the peasant class of the Plain of Reeds disciplined themselves and prepared to become the core force for the monumental transformation of 1945.

In summary, social stratification in the Plain of Reeds was the inevitable result of an extractive economy. The "transformation" here bore the face of suffering but also the face of awakening. Understanding the lives and stratification of the peasantry during this period is not only of historical significance but also fosters an appreciation for the values of social justice in contemporary rural development.

4. CONCLUSION

The study of agricultural economic transformations in the Plain of Reeds from 1867 to 1945 delineates a comprehensive picture of the impact of colonialism on a unique ecological region of Southern Vietnam. The research results indicate that the French conquest of this land was not merely a military occupation but a large-scale process of geographical and economic restructuring. The hydraulic system, featuring strategic canals such as the Lagrange and Tong Doc Loc canals, served as a pivotal technical "lever," converting a desolate, acidic wetland into a commodity rice production hub. According to Duong Van Triem (2018), mechanized dredging fundamentally altered the hydrological regime, facilitating the leaching of acidity and expanding cultivated areas by hundreds of thousands of hectares. However, this intervention was distinctly forced, as infrastructure was designed primarily for resource extraction and security control rather than the sustainable benefits of the local inhabitants.

Concurrent with the transformation of technical infrastructure was the collapse of the traditional land regime, replaced by a system of capitalist private ownership. The implementation of cadastral decrees by the colonial administration led to land accumulation at an unprecedented level in history. According to Brocheux (1995), land concession policies facilitated the formation of a landlord class and French exploitation companies while simultaneously displacing the majority of pioneering farmers into landlessness and tenancy. This transformation established an extremely stratified rural social order, where contradictions between landlords and tenant farmers became more intense than ever. As Phan Huy Le (2012) observed, exploitation through the "rent-tax-interest" system impoverished the peasantry, transforming them into laborers on the very land their ancestors had cleared, thereby creating a "detonator" for the outbreak of resistance movements in the heart of the Plain of Reeds.

Economically, the 1867–1945 period witnessed the Plain of Reeds' transition from a subsistence agricultural base to a commodity-oriented economy integrated into global value chains. The monoculture of rice and the emergence of market towns along canals connected this region with the port of Saigon and international markets. However, this "development" was one-sided and deeply dependent on French capital. According to Martin (2007), the colonial

agricultural economy of Cochinchina was highly vulnerable to global fluctuations, particularly during the Great Depression of 1929–1933. Profits from rice exports primarily flowed into the pockets of financial capitalists and commercial intermediaries, leaving direct producers with burdens of mounting debt. Tran Van Giau's (2006) research also emphasized that despite skyrocketing yields, the actual lives of farmers did not improve proportionally, reflecting the exploitative nature of a typical colonial economy.

From historical and practical perspectives, the transformations in the Plain of Reeds during nearly a century of French rule offer valuable lessons for contemporary regional management and development. Lessons regarding the balance between resource exploitation and wetland ecosystem conservation, as well as social justice in agriculture, remain highly relevant. According to Nguyen Thanh Thuy (2020), an objective evaluation of historical socio-economic institutions helps identify barriers to sustainable development more clearly. In summary, the 1867–1945 period was a tragic yet resilient chapter in the history of the Plain of Reeds. The economic changes of this era not only shaped the rural social face before 1945 but also laid the foundation for perceptions of land sovereignty and revolutionary spirit, contributing decisively to the victory of national liberation and the construction of the Mekong Delta today.

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TOWARD EFFICIENT ENERGY MANAGEMENT OF ISOLATED HYBRID MICROGRIDS INTEGRATING PHOTOVOLTAIC GENERATION, BATTERY STORAGE AND DIESEL GENERATORS

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Abstract :

The increasing demand for reliable and sustainable electricity supply in remote and isolated areas has accelerated the development of hybrid microgrids combining renewable energy sources and conventional generation. Among these configurations, systems integrating photovoltaic (PV) generation, battery energy storage systems, and diesel generators have emerged as a promising solution to improve energy access while reducing dependence on fossil fuels.

This work presents an overview of recent developments in the field of hybrid isolated microgrids and highlights the main challenges associated with their operation. Particular attention is given to energy management strategies aimed at ensuring reliable power supply while maximizing renewable energy penetration.

wincluding the development of efficient energy management strategies to ensure system stability and optimal coordination between photovoltaic production, battery storage, and diesel generation, and also the battery degradation strategies. The second perspective addresses the **economic dimension**, with the objective of reducing the overall cost of electricity production through optimized operation and better utilization of renewable resources. Finally, the **environmental aspect** is considered by investigating approaches that contribute to lowering greenhouse gas emissions and reducing the carbon footprint of isolated power systems.

By highlighting these technical, economic, and environmental challenges, this work aims to provide a clear overview of current research trends and to outline future research directions toward more efficient and sustainable energy management solutions for isolated hybrid microgrids.

SUSTAINABLE APPROACH TO WATER SCARCITY IN ARID AREAS BY USING RENEWABLE ENERGY FOR DESALINATION

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Abstract:

Arid and semi-arid areas, which cover approximately 46% of the Earth's surface, are particularly vulnerable to the combined effects of climate change, desertification, and water scarcity. These constraints lead to the gradual deterioration of ecosystems, a reduction in ecosystem services, and increasing water insecurity affecting approximately three billion people. In this context, water desalination appears to be a strategic solution for enhancing water security in arid areas. This study focuses on examining the major desalination technologies, namely reverse osmosis, thermal distillation, and emerging processes. It highlights their integration with renewable energy sources, such as solar, wind, and geothermal energy. The analysis highlights that coupling desalination with renewable energy reduces carbon footprint, dependence on fossil fuels, and long-term operating costs. Despite the challenges inherent in energy intermittency, initial investment, and brine management, these technologies offer promising prospects for sustainable water management. Desalination powered by renewable energy plays a crucial role in combating climate change and promoting sustainable development in arid and semi-arid regions. It is an essential lever for adapting to climate change, while helping to secure water supplies and promote energy independence.

Keyword: Renewable energy; Water desalination; Water security; Climate change; Renewable energy; Reverse osmosis; Energy efficiency;

UTILIZATION OF OPEN EDUCATIONAL RESOURCES (OER) IN THE TEACHING OF ENGLISH LANGUAGE GRAMMAR IN SENIOR SECONDARY SCHOOLS IN SOUTH EAST NIGERIA

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Abstract

This study investigated the utilization of Open Educational Resources (OER) in the teaching of English language grammar in senior secondary schools in South East Nigeria. Specifically, the study examined the OER accessible to English Language teachers, the extent of their utilization of these resources, the factors hindering effective use, and the strategies for enhancing OER integration in English language grammar instruction. The study adopted a descriptive survey research design. The population comprised 53 English Language teachers in 30 public senior secondary schools in the area, all of whom were used as the sample through simple random sampling. Data were collected using a structured questionnaire developed by the researchers and validated by experts, with reliability established using Cronbach's Alpha coefficient ($\alpha = 0.70$). Mean and standard deviation were used for data analysis, with a criterion mean of 2.50 for decision-making. Findings revealed that English Language teachers have limited access to a wide range of OER, with only a few platforms such as the British Council and selected YouTube channels being accessible. The extent of OER utilization was generally low, as teachers relied mainly on familiar and limited resources. Major factors hindering effective utilization included poor internet connectivity, lack of digital devices, inadequate technical support, and insufficient teacher training. However, teachers strongly agreed on several strategies for improving OER utilization, including regular professional development, improved internet infrastructure, provision of multimedia resources, curriculum integration of OER, and collaborative sharing of materials. The study concludes that addressing these challenges and implementing the identified strategies would enhance the effective utilization of OER and improve the teaching and learning of English language grammar in senior secondary schools.

Keywords: Open Educational Resources, English Grammar

POWER AND MARITIME BORDER TRANSFORMATIONS: EXAMINING THE ROLE OF IRANIAN GOVERNANCE IN THE PERSIAN GULF DURING THE QAJAR PERIOD

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Abstract

The present study aims to analyze in detail the extent and quality of Iranian governance over the coasts and islands of the Persian Gulf during the Qajar period. This historical period was the scene of complex developments in the field of maritime borders and port management due to the increasing competition of European powers, especially England, and at the same time, the relative weakness of the central government. This study, with a historical-analytical approach, attempts to assess the effectiveness of the Qajar government's policies against foreign influence in this strategic region. The main focus will be on the conflicts related to the islands, trade control, and how Iranian sovereignty was stabilized or weakened in the face of external threats. The research findings will show that governance during this period was a fragile balance between maintaining independence and making inevitable compromises to secure local and international interests. This study provides a deeper understanding of the historical foundations of Iran's sovereignty claims in the Persian Gulf. This study seeks to answer the following questions using an analytical-historical method: 1- What was the extent and nature of the Qajar government's rule over key ports and islands of the Persian Gulf during the Qajar period, and what factors played a role in stabilizing or weakening this rule? 2- How did Iran's interactions with colonial powers (especially Britain) on the issue of maritime borders and control of Persian Gulf trade during this period affect Iran's regional power structure? The findings of the study indicate that Iran's rule over the Persian Gulf during the Qajar period was not a centralized and unified system, but rather a form of dispersed rule that was mainly secured through treaties and influence over local rulers and was highly vulnerable to British pressure. Competition from foreign powers, especially Britain's military and commercial entry into the region, played a major role in defining and weakening the boundaries of Iran's maritime borders and forced the Qajar central government to accept limitations in the internal management of the Persian Gulf.

Keywords: Persian Gulf, Qajar, England, local governance, maritime demarcation.



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