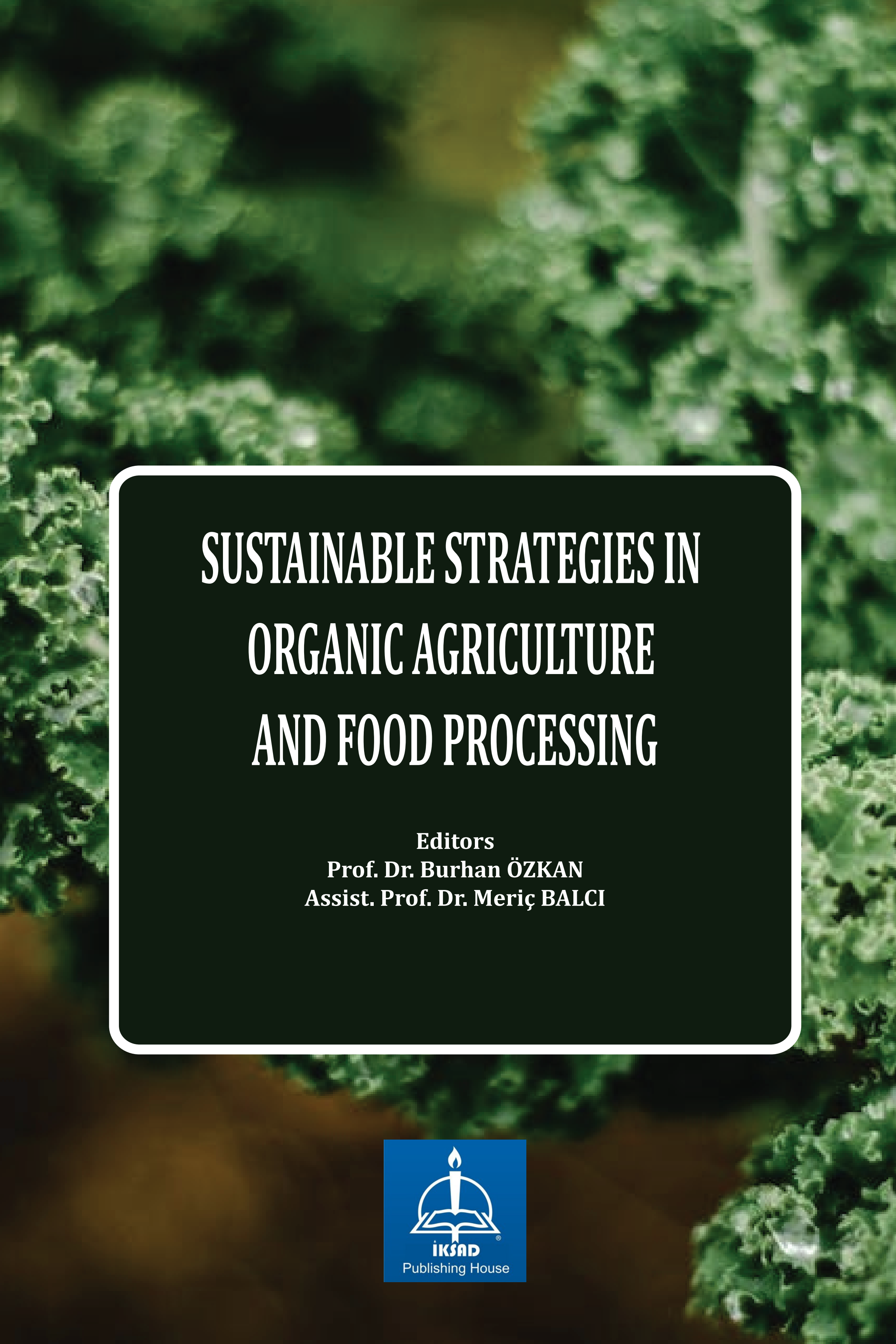

SUSTAINABLE STRATEGIES IN ORGANIC AGRICULTURE AND FOOD PROCESSING

Editors
Prof. Dr. Burhan ÖZKAN
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CONTENTS

PREFACE

Greetings to readers of "Sustainable Strategies in Organic Agriculture and Food Processing." Within the pages of this academic compilation, we embark on a journey through the intricate landscape of sustainable practices, exploring the symbiotic relationship between organic agriculture and food processing. As the world grapples with pressing challenges in food security, environmental sustainability, and climate change, the need for innovative and sustainable solutions has become paramount.

This book is the result of collaborative efforts, bringing together leading scholars and researchers who share a commitment to advancing our understanding of sustainable agriculture and food production. The varied chapters within this volume cover a broad spectrum of topics, offering insights into the principles and applications that define sustainable practices in the realm of organic agriculture and food processing.

Contributors delve into the historical context and ecological foundations of organic farming, illuminating the principles that guide practitioners toward holistic, sustainable approaches. From soil health to biodiversity conservation, these chapters lay the groundwork for comprehending the interconnected factors crucial for successful organic farming practices.

Shifting focus to sustainable food processing, the book explores innovative technologies, ethical considerations, and best practices. Emphasizing waste reduction, resource optimization, and minimized environmental impact, contributors discuss how food processing can align with and amplify the principles of organic agriculture.

As editors, we express our gratitude to the contributors who have dedicated their time and expertise to this endeavor. Their collective wisdom and commitment to sustainability exemplify the potential for positive change within our food systems. May this book serve as a valuable resource, inspiring new ideas, fostering interdisciplinary collaboration, and motivating the next generation of scholars and practitioners to contribute to the ongoing evolution of sustainable strategies in organic agriculture and food processing.

Editors

CHAPTER I

MAPPING AND VISUALIZATION OF RESEARCH ON FOOD WASTE IN THE CONTEXT OF SUSTAINABILITY: A BIBLIOMETRIC ANALYSIS

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INTRODUCTION

With the emergence and rapid rise of industrialization, three critical main parameters have shown significant growth: human population (1), urban development commensurate with this population (2), and waste production from urban housing and industry (3) (Bhattacharjee et al., 2023). Population growth, industry development, and urbanization directly contribute to an increase in waste production (Rana et al., 2015). Consequently, the concept of sustainability has become widespread, leading to the emergence of sustainability-related studies (Weber and Hogberg-Saunders, 2018).

"Any substance or material that is thrown into the environment or left or has to be thrown away by its producer or the real or legal person who actually possesses it" is the definition of "waste" as given by the Waste Management Regulation (Waste Management Regulation, 2015). In 2022, a total of 109.2 million tons of urban and industrial waste were produced in Turkey (TUIK, 2022). A noteworthy type of waste in recent years is food waste, typically described as the disposal of edible foods by consumers or retailers (Yılmaz Tuncel, N., 2019). Of the total waste generated in Turkey, 5%, equivalent to 5.46 million tons, originates from the food, beverage, and tobacco product manufacturing sectors (TUIK, 2022). China (91.6 million tons), India (68.7 million tons), and the United States (19.4 million tons) are the top three countries in terms of yearly food waste production (Table 1). The sustainable management of food waste, whose quantity continues to escalate and will persist as long as humanity exists, holds significant importance for both human and environmental health. Considering that a substantial portion of food waste results from waste, the gravity of the issue intensifies. For sustainable waste management, one of the most prioritized practices recommended for food waste is to reduce waste at the source and subsequently convert the resulting waste into valuable components (such as carbohydrates and proteins) (Guggisberg, 2022; Tonini et al., 2018). Various methods, including storage, incineration, anaerobic fermentation, compost, and worm compost production, are widely used in food waste disposal (Songür and Çakıroğlu, 2016; Uzun, 2023), with an increasing number of scientific studies providing guidance for practical waste management practices and proving to be essential.

Table 1. Annual amounts of food waste in countries (Lahiri et al., 2023)

Country	Amount of food waste (million tons)
Chinese	91,6
India	68,7
USA	19,4
Japan	8,20
Germany	6,30
France	5,50
England	5,20
Russia	4,90
Spain	3,60
Australia	2,60

In this study, the bibliographic visual mapping method was employed to examine academic scientific research on food waste and sustainability from an intellectual perspective. The investigation delved into various bibliographic indicators, including publication trends, sources, authors, document analysis, and detailed network analysis within scientific studies addressing food waste in the context of sustainability.

METHODOLOGY

Search Strategy and Mapping Analysis

In this study, the aim is to present a visual bibliographic analysis of scientific studies on food waste and sustainability published between 2003 and 2023. Bibliographic analysis, through the application of the visual mapping technique, enhances the comprehensibility of quantitative data and serves as a guide for new researchers interested in the analyzed scientific thematic field.

Web of Science (WoS) and Scopus are commonly utilized literature databases in bibliometric studies (Torres-Salinaz et al., 2009; Archambault et al., 2009). Within the scope of this study, a keyword-based search strategy was implemented, scanning the keywords "food waste," "waste food," and "sustainability" in the Web of Science (WoS) database under the TITLE-ABSTRACT-KEYWORDS category. A total of 1425 scientific articles were obtained by filtering from the Web of Science database and were subsequently analyzed in the study (Table 2). Only scientific studies classified as articles were considered, while Early Access, book chapters, and proceeding papers were excluded.

The study utilized various WoS indexes, including Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index Science (CPCI-S), Emerging Sources Citation Index (ESCI), Book Citation Index Science (BKCI-S), Book Citation Index Social Science & Humanities (BKCI-SSH), and Arts & Humanities Citation (A&HCI). Mapping analysis was employed to reveal the number of scientific studies in which the searched keywords appeared together in the database. This analysis conducted using VOSviewer software developed at Leiden University CWTS (Van Eck & Waltman, 2010) and R-Studio Biblioshiny software (Aria & Cuccurullo, 2017), exposed the structure and boundaries of the scientific subject (Börner, 2010).

Table 2. Research procedure

Parameters	All data used in the study
Database selection	Web of Science (WoS) https://www.webofscience.com/wos/woscc/basic-search
Search criteria	Topic (Searches title, abstract, author keywords and Keywords Plus.)
Topic	"Waste food" or "food waste" **And** sustainability
Timespan	2003-2023 (30 years)
Document type	Article
Number of articles	1425
Analysis programs used	VOSviewer version 1.6.20 and RStudio-Biblioshiny
Publish Language	English
Date of access	02.11.2023

RESULTS AND DISCUSSION

General Results

The oldest study was conducted in 2003, and the newest study was conducted in 2023, covering a period of 20 years. It is observed that studies on food waste and sustainability involved 5275 authors across 1425 articles and were published in 468 different scientific journals (Table 2). However, the impact levels of these sources are not equal, as certain journals contribute more significantly to scientific studies in this field than others. Bradford's law categorizes all source journals into three main zones: Zone 1 (highly productive zone), Zone 2 (medium productive zone), and Zone 3 (low productive zone) (Bhattacharjee et al., 2023). In this context, 7 journals fall into Zone 1,86 journals into Zone 2, and the remaining 375 journals into Zone 3.

The average number of citations per article is 22.59, and the average number of authors per article is 4.47. The number of single-author publications is 84, with 95 publications having a single author. A total of 70341 references were utilized in all publications (Table 3). As depicted in Figure 1, it has been determined that the number of publications per year has steadily increased since 2012. When examining the distribution of scientific studies according to WoS categories, it is observed that 41.89% fall within the Environmental Sciences category, 28.49% in the Green Sustainable Science Technology category, 20.28% in the Engineering Environmental category, and 13.89% in the Food Science Technology category (Figure 2).

Table 3. Main information about data

Description	Results
Sources (Journals, Books, etc.)	468
Documents	1425
Document average age	2,81
Average citations per doc	22,59
References	70341
Document Contents	
Keywords plus (ID)	2799
Author's keywords (DE)	3908
Authors	
Authors	5275
Authors of single-authored docs	84
Authors Collaboration	
Single-authored docs	95
Co-Authors per Doc	4,47
International co-authorships %	33,75

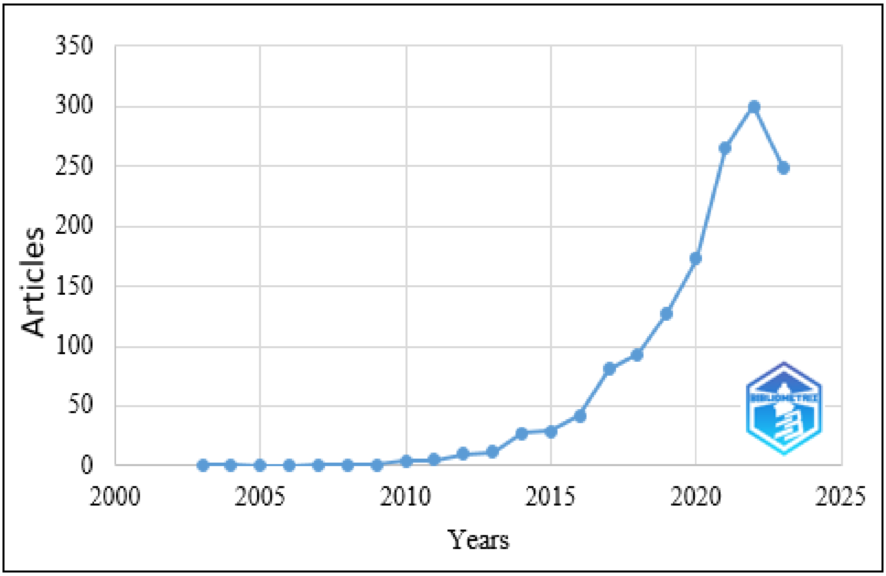
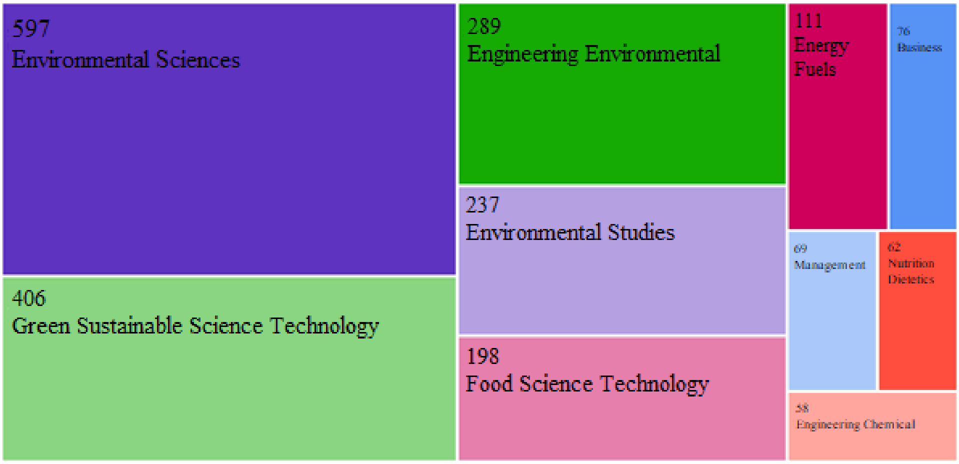


Figure 1. Annual scientific production

Figure 2. Distribution of studies according to WoS Categories



Co-authorship of authors

According to the co-authorship analysis, 1000 networked maps were created based on the criteria of a minimum of 1 publication and a minimum of 1 citation to identify the most collaborative authors. When examining authors with the highest connections between them, an author network map consisting of 9 clusters and 89 authors in co-author collaboration emerges (Figure 3). The highest density in studies containing the keywords "food waste" and "sustainability" is formed around authors Lin, Carol Sze Ki; Pandey, Ashok; and Taherzadeh, Mohammad J (Figure 4).

It is also observed that the most cited authors (Papargyropoulou , Lozano Rodrigo with 743 citations, Lens Piet N.L. with 648 citations, etc.) are not authors who are in very close relations with each other. Authors who produce the most works also appear to be among those with high potential for collaboration.

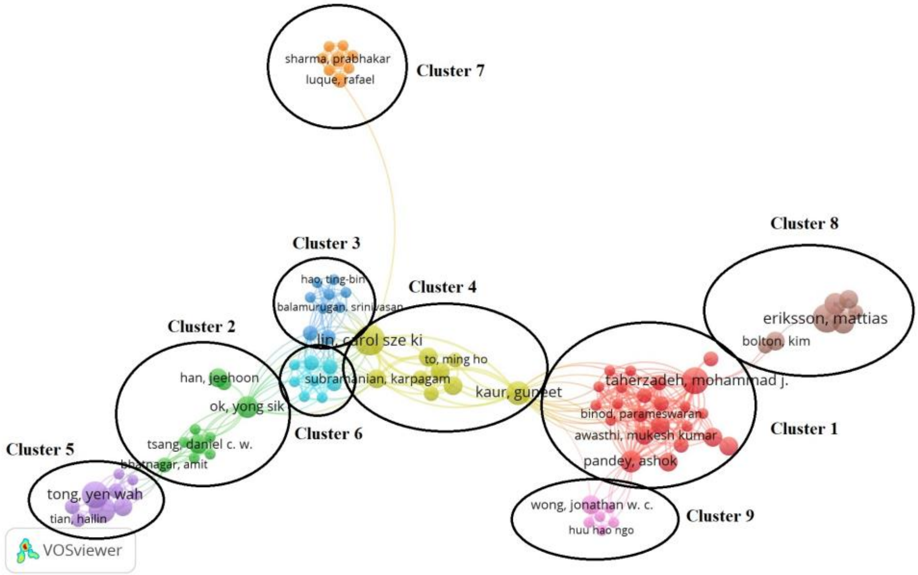


Figure 3. A Co-authorship network map showing collaboration between authors.

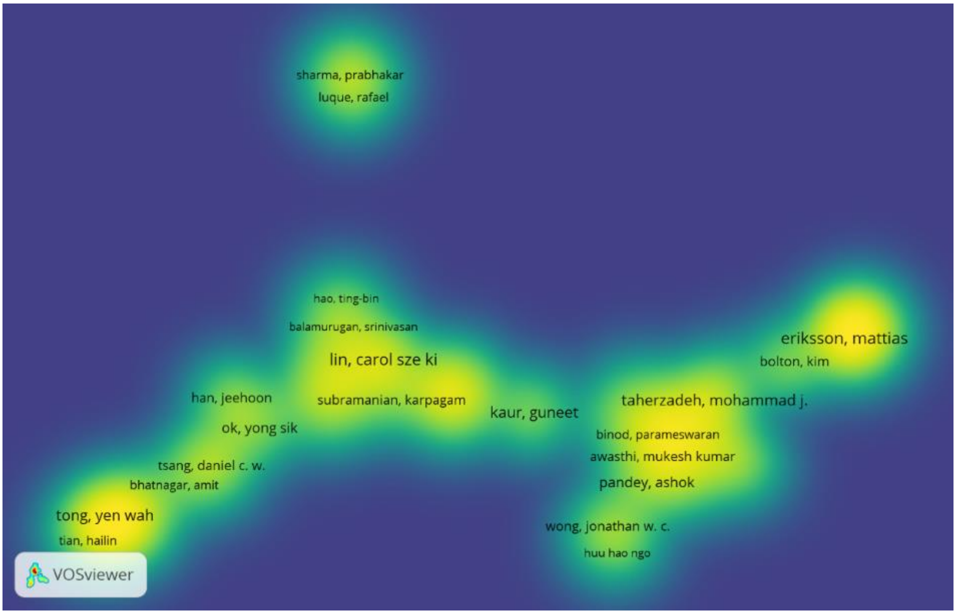


Figure 4. Density map of authors in co-authoring relationships

Authors' Citation Analysis

To identify citation networks, a network map of author-citation analysis was created with a minimum requirement of 1 publication for authors and a minimum of 50 citations per article (Figure 5). Upon examination of Figure 5, an author-citation network map with 21 different clusters and a total of 544 authors is evident. The first three most cited authors are Papargyropoulou et al., Ariunbaatar et al., and Galanakis, with 743, 578, and 493 citations, respectively. The author with the highest annual average citations (123.25) is Galanakis, while Leclère ranks second with 76 citations per year (Table 4).

The article by the most cited author (Papargyropoulou et al., 2014) has established its presence in the literature and the scientific world with the title "*The food waste hierarchy as a framework for the management of food surplus and food waste.*"

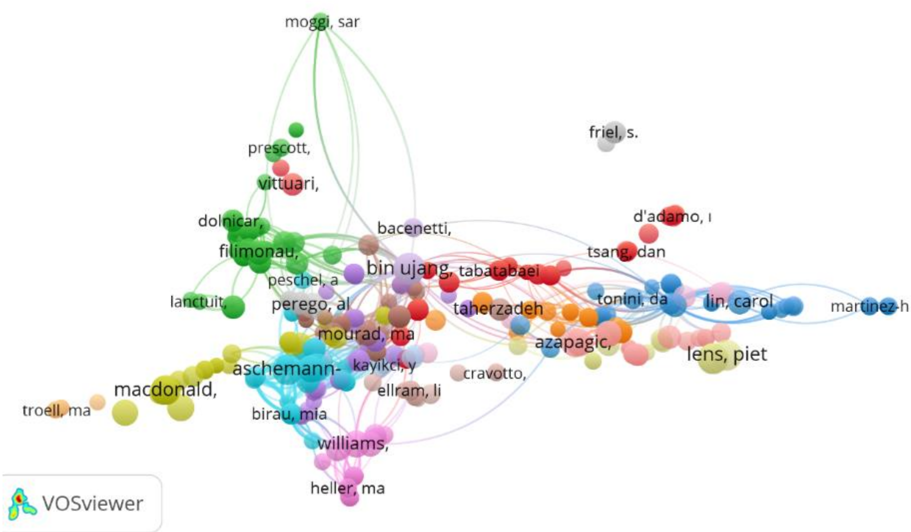


Figure 5. Authors' citation analysis map

Table 4. Most global cited documents, DOI and total citations (TC) (R-Studio Biblioshiny)

Author, Year, Journal	DOI	TC	TC per Year
Papargyropoulou et al., 2014, Journal of Cleaner Production	10.1016/j.jclepro.2014.04.020	743	74,30
Ariunbaatar, 2014, Applied Energy	10.1016/j.apenergy.2014.02.035	578	57,80
Galanakis, 2020, Foods	10.3390/foods9040523	493	123,25
West et al., 2014, Science	10.1126/science.1246067	483	48,30
Crews &Peoples, 2004, Agriculture, Ecosystems & Environment	10.1016/j.agee.2003.09.018	360	18,00
Leclère, 2020, Nature	10.1038/s41586-020-2705-y	304	76,00
Chaudhary et al., 2018, Nature Communications	10.1038/s41467-018-03308-7	260	43,33
Wirsenius et al., 2010, Agricultural Systems	10.1016/j.agsy.2010.07.005	241	17,21
Garrone et al., 2014, Food Policy	10.1016/j.foodpol.2014.03.014	218	21,80
Mourad, 2016, Journal of Cleaner Production	10.1016/j.jclepro.2016.03.084	217	27,13

Citation Analysis of Countries and Countries Collaboration

When creating the VOS viewer network map to analyze citations received by publications on a country basis, we examined 58 observations related to countries that have at least one work and received a minimum of one citation. The analysis revealed that 93 countries worldwide are cited in studies related to 'food waste and sustainability.' The USA, England, Italy, and the Netherlands have the highest number of citations, with 6411, 6307, 5482, and 4025 citations, respectively. Turkey is ranked 27th in this citation ranking with 581 citations (Figure 6). Regarding Turkey's connections in 'food waste and sustainability' studies, the countries with the most relations are the USA, Italy, England, Spain, Denmark, and Brazil.

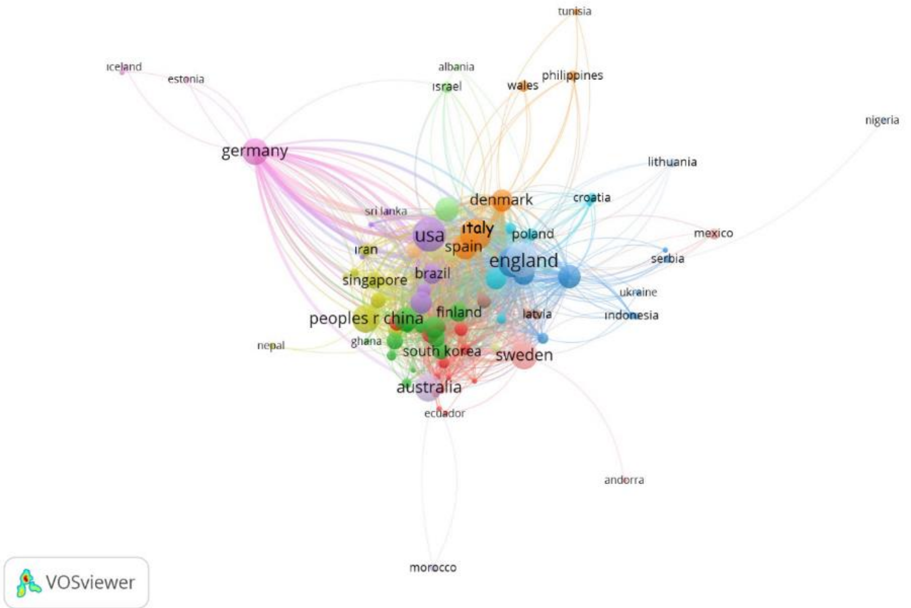


Figure 6. Citation analysis of countries

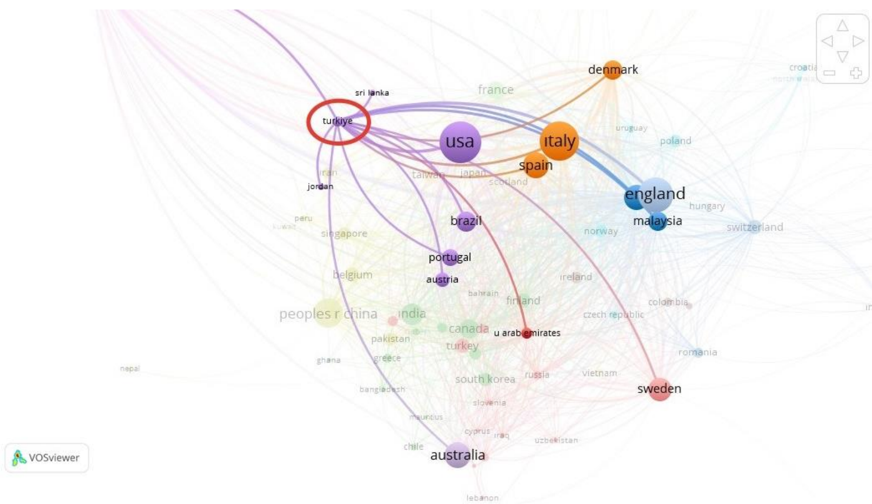


Figure 7. Turkey's citation relationship map with other countries

When analyzing the relationships between countries in the context of food waste and sustainability, it is observed that the USA collaborates most frequently with China (frequency=26) and subsequently with the United Kingdom (England) (frequency=19). Additionally, there is a notable frequency of scientific publication collaborations between Italy and the Netherlands (frequency=15) (Figure 8, Table 5).

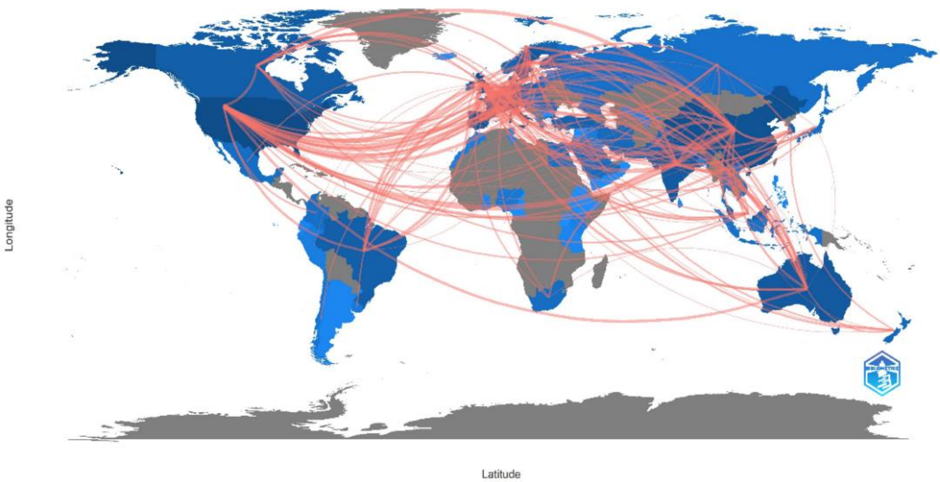


Figure 8. Countries' Collaboration World Map (Biblioshiny)

Table 5. Countries with the 10 highest frequencies (R-Biblioshiny)

From	To	Frequency
USA	China	26
USA	United Kingdom	19
United Kingdom	Netherlands	18
United Kingdom	China	17
USA	Netherlands	17
Italy	Netherlands	15
Italy	France	14
Italy	Spain	14
United Kingdom	Germany	13
United Kingdom	India	13

When examining the analysis of the countries from which the responsible authors in the studies originate, it is observed that 175 authors are from Italy. However, among these authors, 131 have an Italian responsible author, and the remaining authors are also from Italy. Among the remaining 44 responsible authors from Italy, it has been determined that at least one of the other authors in the publications is from a different country. Similarly, the USA, the United Kingdom, China, and Spain follow this pattern with 172, 125, 112, and 62 authors, respectively. The analysis reveals that 26 authors responsible for the studies are from Turkey, placing them 16th in this list (Figure 9).

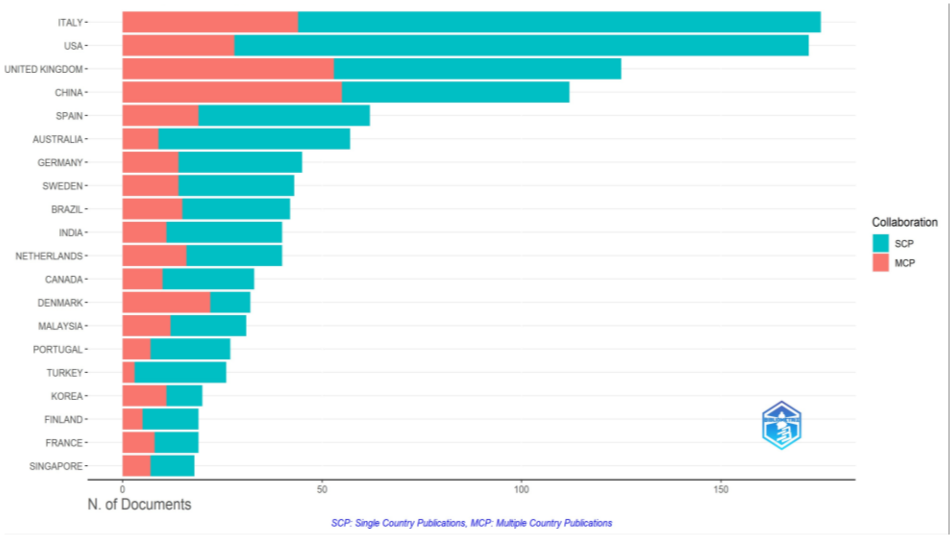


Figure 9. Corresponding author's countries

Citation of Organizations

To create a network map of the citations received by institutions, an analysis was conducted on 539 observation units with relationships between them. The criteria for inclusion were that an institution had published at least 2 publications and received at least 2 citations. The analysis revealed that Leeds University, University of Technology-Malaysia, Aarhus University, and Utrecht University had the most citations, with 10 documents and 1107 citations, 7 documents and 995 citations, 19 documents and 956 citations, and 4 documents and 848 citations, respectively (Figure 10).

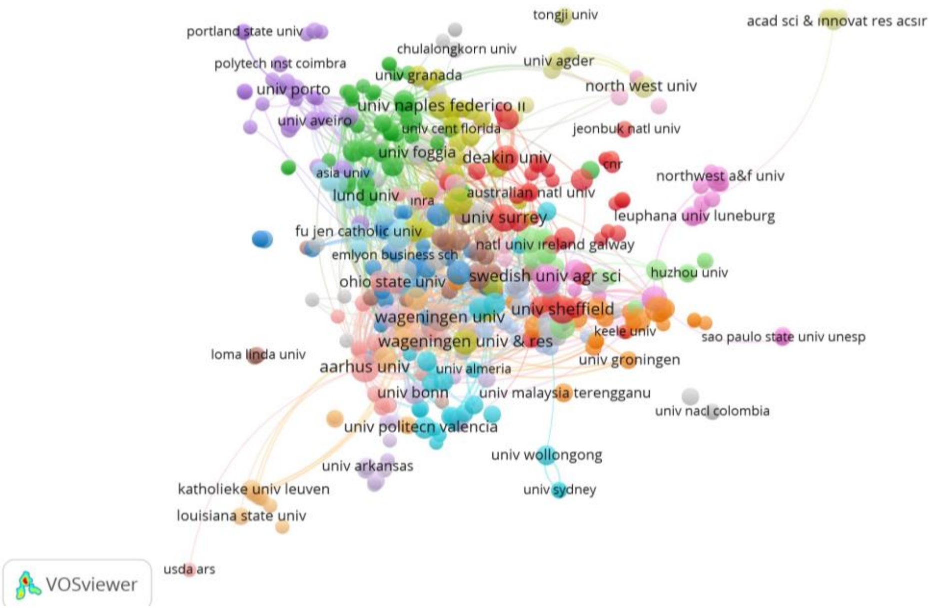


Figure 10. Citation network map of organizations

Keywords Used in Studies

The abstract and keyword sections of scientific studies containing the keywords 'food waste' and 'sustainability' were analyzed to identify the most frequently used keywords. The analysis revealed that the most frequently used keywords were 'food waste' (523 times), 'sustainability' (480 times), 'circular economy' (121 times), 'life-cycle assessment' (79 times), and 'waste management' (59 times) (Figure 11). As these keywords belong to both social and scientific sciences, the subject is considered to be interdisciplinary.

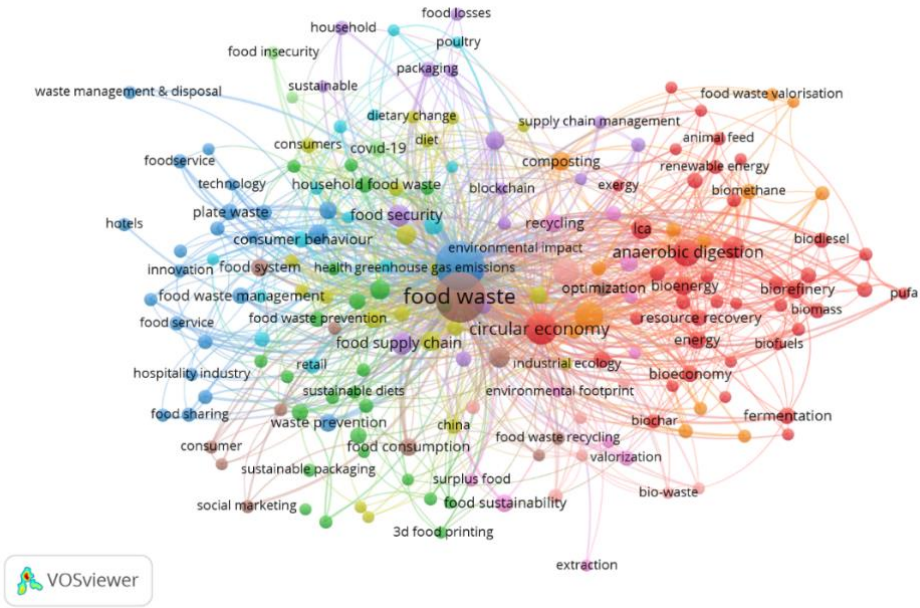


Figure 11. Most frequently used words and usage percentages

CONCLUSIONS

This study presents a global research trend analysis on the concept of food waste and sustainability based on scientific literature available from 2003 to 2023 in the Web of Science database. A total of 1425 articles were extracted from the Web of Science database and analyzed using various bibliometric parameters. According to the analysis results, it was observed that scientific studies on food waste and sustainability have been ongoing since 2003, with a significant increase in publications in 2012 and a peak of 300 articles in 2022. The majority of research has been conducted in the USA, Italy, the United Kingdom, and China, respectively. These four countries, which are also actively involved in fostering international collaboration, appear to serve as inspiration for writers and other nations. According to Bradford's Law, seven sources out of 468 (journals) were identified as the most significant contributors to this field. While a large number of authors (5275) contribute to the field of food waste and sustainability, 1.61% of these authors produce articles with a single title. The number of authors producing more than five articles has been determined to be 30. Out of these, 156 authors received more than 50 citations in their articles, and the most- cited author amassed 743 citations.

When analyzing the addresses of responsible authors in the articles produced, it was found that the addresses of 175 authors were in Italy, ranking Italy as the leading country in the responsible author analysis. In keyword analysis, it was observed that studies initially focused on waste management until 2012, but in subsequent periods, themes such as waste management, food waste, sustainability, life cycle analysis, circular economy, and anaerobic digestion frequently emerged.

For recent and future trends in sustainable food waste management, studies on energy production under anaerobic conditions (biogas), waste minimization modeling, environmental risk analysis for the food sector, greenhouse gas emission and carbon footprint calculations, and waste prevention in human food consumption are recommended. New scientific studies on the evaluation and disposal of food waste will contribute to making sustainable food production and conscious consumption more achievable.

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CHAPTER II

EVALUATION OF AGRICULTURAL WASTES AS INPUT IN AGRICULTURE: VERMICOMPOSTING OF JUNIPER SEED WASTES

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INTRODUCTION

With the increase in urbanization and industrialization, the amount of waste resulting from people's daily lives is increasing day by day. Nowadays, especially considering the rise in ready-made foods and packaged products, there is an increase in the amount of recyclable waste. However, since organic waste is disposed of as domestic waste, no benefit can be obtained from the waste, and waste storage areas fill up quickly. Composts are valuable products that can be used as organic matter on agricultural lands (Raj and Antil, 2011).

The amount of waste collected by municipalities is increasing daily, correlating with population growth. Domestic waste encompasses kitchen waste, recycling waste, and other waste. According to TURKSTAT data, while the total amount of domestic and recycling waste was 25.1 million tons in 2001, this value increased, reaching 32.3 million tons of waste in 2020 (Figure 1).

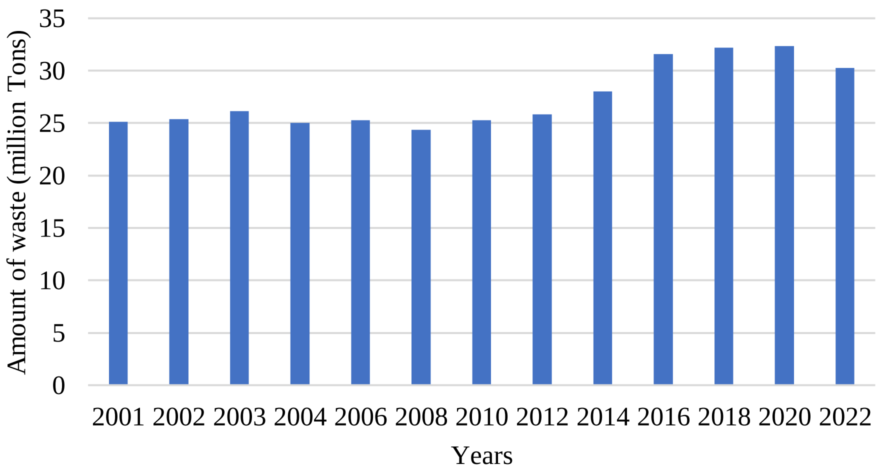

Figure 1. Amounts of waste collected by municipalities.

Due to our country's reliance on agriculture and animal husbandry, the waste problem is on the rise, primarily due to the increasing number of animals. When the animal manure resulting from these activities is not appropriately managed, it contributes to various environmental issues, particularly underground and surface water pollution. Employing an environmentally friendly approach to address solid waste problems through the composting process not only helps prevent leachate, groundwater pollution, and odors but also results in a recyclable product that can be utilized in agriculture and horticulture (Paulin and O'Malley, 2008).

The escalating amount and volume of organic-containing solid waste can be reduced through biological decomposition, alleviating the burden on landfills by minimizing non-reactive waste. Challenges in finding landfill sites globally, including in our country, have made composting an attractive solution to waste reduction. Composting can reduce dependence on chemical fertilizers and environmental pollution (Öztürk, 2022; Bekchanov and Mirzabaev, 2018).

Composting is the controlled aerobic biological decomposition of organic material (Epstein, 1997). Within integrated solid waste management systems, composting is gaining popularity as a cost-effective method for solid waste with organic components (Sesay et al., 1998). The composting process protects raw material resources through recycling, ensures a healthy utilization of solid waste, and extends the useful life of landfills.

The decomposition rate of organic waste during composting varies based on waste type and composition. While animal-based wastes undergo a relatively rapid composting process, plant-based wastes, owing to their cellulosic and lignin structures, take a longer time. According to Haug (1993), at the outset of the process, easily degradable organic compounds like simple carbohydrates, fats, and amino acids break down quickly, whereas robust organic substrates with cellulose, hemicellulose, and lignin structures are only partially broken down and transform slowly.

The general goals of composting include: (1) converting decomposable organic substances into biologically stable substances; (2) eliminating pathogens, insect eggs, other undesirable organisms, and weed seeds present in solid waste; (3) maximizing the nutritional element content (nitrogen, phosphorus, and potassium); and (4) producing a product that supports plant growth and can be used as a soil conditioner (Tchobanoglous, 1993).

Standard composting systems are (Ensberger, 1995);

- Pile composting
- Cell composting or composting containers

- Composting tunnels and row composting systems
- Fermentation towers
- Composting of pressed materials
- Rotary drum composting

Some of the benefits of compost are (EPA, 2023):

- Conversion of organic solid wastes into biologically stable end products
- Using the resulting product in agriculture, horticulture, and other fields (such as soil improvement, organic fertilizer, and landscaping work).
- Effective removal of pathogenic bacteria in waste
- Saving solid waste from regular landfills
- Providing soil erosion control
- It increases the void volume of the ground, facilitates its ventilation, and increases its water retention ability.
- Enables easy processing of difficult to work soils.
- It acts as a buffer against high mineral fertilization and thus prevents damage to plants.
- Better use of nutrients
- Reducing fertilizer consumption, thereby reducing environmental pollution, and saving economic expenses

The usage areas of compost are (EPA, 2023):

- In field, garden applications, greenhouse cultivation, fruit growing, nursery, floriculture, and medicinal plant plantings.
- Golf courses, landscaping works, grass fields, parks and playgrounds, roadsides, cemeteries, and military facilities
- In the rehabilitation of mined areas, old sand, and gravel pits, and in erosion control
- As filter material for odor removal
- As final cover material in landfills
- In the rehabilitation of burned forest areas

Basic parameters effective in the composting process can be listed as temperature, C/N ratio, pH, SM, aeration, and mixing. For a rapid composting process, C/N: 25/1-30/1, SM: 50-60%, pH: 6.5-8.0 and temperature: 55-60 °C are recommended (Rynk, 1992).

The red California worm (*Eisenia fetida*) is a species of worm, and its anatomical structure is shown in Figure 2. It is the most common type used in worm composting today.

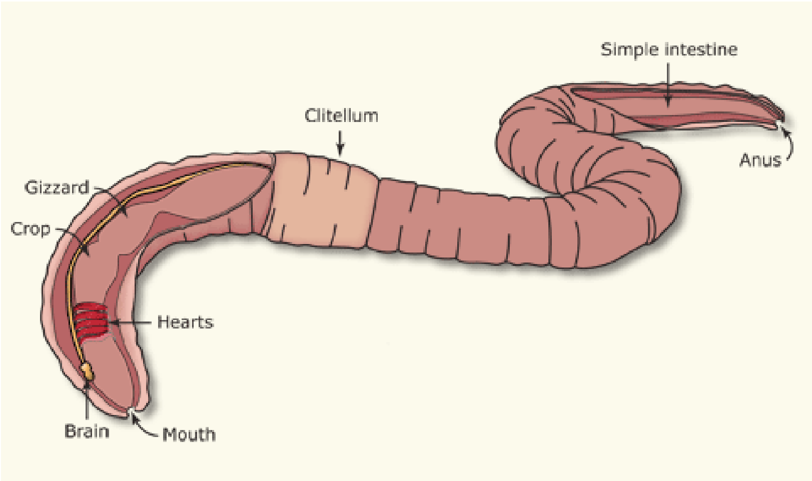

Figure 2. Diagram of a worm (Yeates, 2023)

An adult worm produces between 0.6 and 2.6 eggs per week as a result of copulation. Each egg contains an average of 10-20 mg. These eggs emerge as hatchlings after 8-12 weeks of incubation. The hatchings become juvenile worms after 11-15 weeks. Juvenile worms become adults when they reach a weight of 450-700 mg (Figure 3).

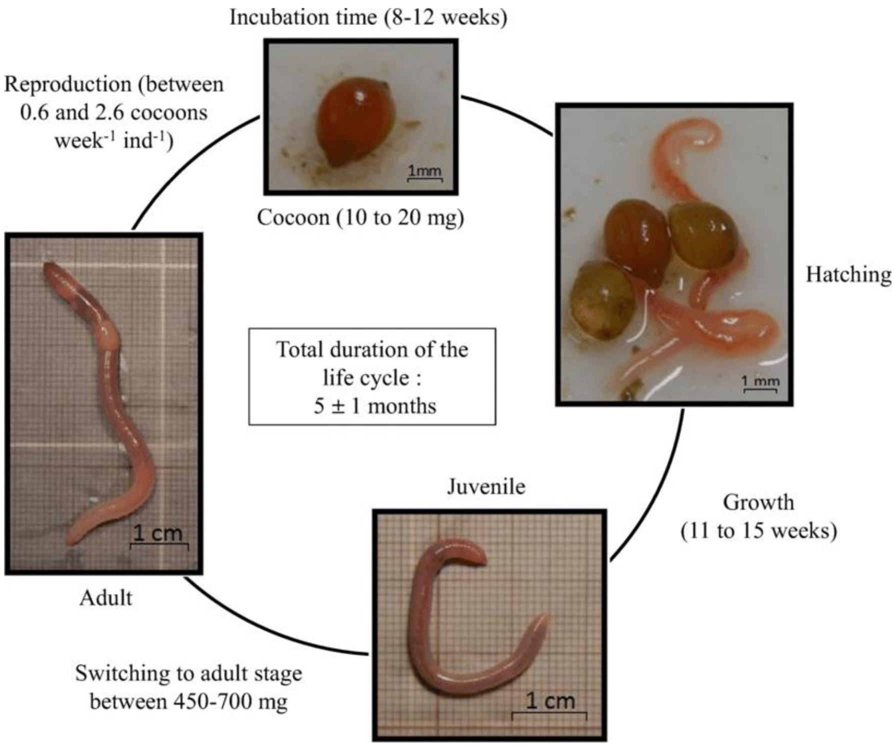

Figure 3. Life cycle of the worm (Barth et al., 2018)

Organic wastes are combined with various materials and composted at different mixing ratios. Through the composting process, waste transforms into compost, resulting in a stable product. Subsequently, the resulting compost is introduced to worms for vermicomposting. In this process, compost is excreted as feces following its consumption by worms. The process flow for vermicompost production from organic waste is illustrated in Figure 4.

Figure 4. Process flow

COMPOSTING

Composting Materials

The composting process took place at the Yeşil Vadi Red Worm Farm facilities in Isparta. The juniper berry seeds (JB) used in the study were obtained from a local farmer, and the oil extracted from these seeds was utilized. Additionally, dairy manure (DM) was sourced from the Isparta Applied Sciences University Farm, while plane leaf (PL) and corn plant harvest residues (CPR) were obtained from Isparta Sav town. The physical and chemical properties of the materials involved in the composting process are detailed in Table 1.

Table 1. Physical and chemical properties of the materials used in the composting process (Sülük et al., 2018)

Parameters	JB	DM	PL	CPR
MC (%)	16.14	31.7	59.27	4.53
OM (%)	93.15	61.23	85.98	92.26
pH	7.24	8.85	7.43	9.71
EC (dS/m)	0.89	2.05	0.69	2.03
TC (%)	31.66	22.89	28.42	30.48
TN (%)	0.79	1.59	0.61	0.41
C/N ratio	40.08	14.40	46.59	74.34

The mixing ratios of these materials, based on dry matter, at the initiation of the composting process are presented in Table 2. A visual representation of the compost pile prepared for the study can be observed in Figure 5.

Table 2. Compositions of the mixtures and initial C/N ratios

Materials	P1	P2	P3	P4
JB, %	25	47	68	77
DM, %	65	43	27	13
PL, %	5	5	5	5
CPR, %	5	5	5	5
C/N	20	25	30	35

Figure 5. Composting pile

Analytical Metod

Duplicate samples were collected both at the initiation and conclusion of the vermicomposting process. The moisture content of the fresh samples was determined subsequent to drying them at 70±5°C for a period of 3 days. The analysis of organic matter content in dry samples was conducted by incinerating the samples at 550°C, following the guidelines recommended by the USCC (2002).

The pH and electrical conductivity (EC) of the fresh samples were extracted through a shaking process at 180 rpm for 20 minutes with a solid to water ratio of 1:10 (w/v). The measurements were carried out using pH and EC meters, specifically Models WTW pH 720 and WTW Multi 340i, respectively. Nitrogen content was analyzed using an elemental analyzer, namely the Vario MACRO CN Elemental Analyzer.

For the assessment of heavy metals and micronutrients, ICP-MS chromatography was employed in the analysis process.

VERMICOMPOSTING

In the composting process, JB, DM, PL, and CPR were utilized. The composting procedure involved the creation of four piles (P1, P2, P3, P4), each with different C/N ratios (35, 30, 25, 20). Across the mixtures, the proportion of JB decreased from P1 to P4, while the proportion of cattle manure increased. In all mixtures, PL and CPR were used in equal amounts. The active composting phase lasted for 30 days, during which the heap temperatures reached up to 68°C in the initial days, eventually dropping to ambient temperature by the end of the composting period. Subsequent to completing the composting process, the same mixtures were employed for worm composting.

In this study, compost with four different mixtures, incorporating worms (*Eisenia fetida*), along with JB, DM, PL, and CPR, was utilized at the Yeşil Vadi Red Worm Farm facilities. Throughout the worm composting process, the water content of the mixtures was maintained at levels between 55% and 60%.

Approximately 2000 adult worms (*Eisenia fetida*) were introduced into each mixture. The worm composting process spanned 120 days and was conducted in 600-liter volume pools, as illustrated in Figure 6. Upon the conclusion of the worm composting process, the worms were separated from the mixture, rendering the compost ready for use.

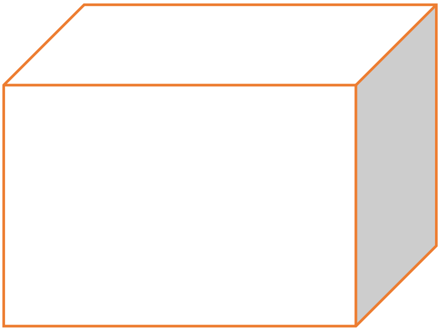

Figure 6. Vermicomposting pool (l:100 cm, w: 110 cm, h: 55 cm)

Vermicompost was produced by subjecting the compost obtained from pile composting to the activity of worms. The results of physical and chemical analyses for four different vermicomposts (W1, W2, W3 and W4) are presented in Table 3. Examining the organic matter content reveals an increase from W1 to W4, with the highest organic matter (OM) value recorded in W4 at 64.4%. Nitrogen and potassium values also demonstrated an ascending trend from W1 to W4, with the highest values observed in W4 at 1.26% for nitrogen and 2.03% for potassium.

Table 3. Physical and chemical properties of the vermicompost

Parameter	W1	W2	W3	W4
pH	7,75	7,91	7,63	7,51
EC, dS/m	3,53	2,83	2,48	2,92
MC, %	55,2	42,2	58,3	54,1
OM, %	46,6	54,1	63,6	64,4
Nitrogen, %	0,61	0,71	1,34	1,26
Phosphorus, %	1,20	1,05	0,86	0,85
Potassium, %	1,74	1,98	1,86	2,03
Calcium, %	7,02	5,53	4,65	4,93
Magnesium, %	1,43	1,10	0,94	0,91
Copper, ppm	84,1	88,0	54,2	49,8
Zinc, ppm	419,1	316,5	225,9	215,1
Manganese, ppm	369,6	320,7	227,5	235,5
Iron, ppm	2611	2337	2187	2819

CONCLUSION

Organic waste can be transformed into compost, a valuable product, through the composting method, which constitutes one of the waste disposal systems.

This study delves into the composting and vermicomposting capabilities of juniper berry seeds (JB), dairy manure (DM), plane leaf (PL), and corn plant residues (CPR) when combined in varying mixing ratios. Upon analyzing the vermicompost results, it was observed that the values of organic matter (OM), nitrogen, and potassium increased with the rise in JB content in the mixture.

The potential for agricultural wastes to undergo composting alongside wastes with diverse organic content in different mixing ratios signifies a promising input source for agriculture. Through this approach, the sustainability of the organic matter cycle is effectively maintained.

ACKNOWLEDGMENT

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CHAPTER III

THE INDUSTRIAL SIZE, NUTRITIONAL VALUE AND HEALTH BENEFITS OF SESAME

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INTRODUCTION

It is vital to provide the human metabolism with enough balanced nutrients to meet its energy needs, which in turn dictates that basic human needs for nutrition must be addressed. This essential tenet underscores the desire to integrate a diverse array of foods into daily life, establishing nutrition as a fundamental requirement for human well-being (Beşirli, 2010).

Understanding societies' perceptions and perspectives on nutrition reveals a cultural inertia, where dietary habits persist over time. However, the advent of new products, coupled with technological advancements, prompts the reconsideration of these habits. Over the past five decades, nutritional research has witnessed a paradigm shift, with a heightened focus on functional foods (Balcı, 2022). Notably, the positive effects attributed to vegetable oils have been pivotal in steering this shift (Tan et al., 2015a). Vegetable oils, rich in natural antioxidants, essential oils, vitamins, and minerals, have evolved from being fundamental components of human diets, from the earliest civilizations to the present day (Tan et al., 2015b). Sesame, among these vegetable oils, is a noteworthy oilseed plant extensively consumed in daily life, embedded in meals, cakes, and various culinary products, owing to its significant fat and protein content (Tan et al., 2015a).

Sesame (*Sesamum indicum L.*) stands out as a plant with a rich historical legacy, being the first oilseed plant cultivated globally. With a cultivation history exceeding 5000 years, sesame has entrenched itself in human culture, finding applications in bakery products, spices, confectionery, tahini, and traditional desserts (Tan et al., 2013).

The seeds of the sesame plant, categorized as a summer oil crop, boast an oil content ranging from 50-60% and a protein content of 25%, contingent upon variables such as species, climate, soil, and production methods. The resulting oil is recognized as a high-quality edible oil, characterized by a substantial concentration of unsaturated fatty acids, particularly oleic and linoleic acids. The stability and prolonged shelf life of sesame oil, attributed to the antioxidant sesamol in its composition, render it suitable for applications in margarine production. While sesame holds a significant position in global vegetable oil production, its economic viability as an edible oil in specific regions, including our country, remains limited. In contrast, Asian countries, with intensive sesame production, widely utilize sesame as a vegetable oil and incorporate it into diverse culinary and industrial products. Notably, Manavgat Golden Sesame in Turkey is identified by its geographical designation and is widely used in the production of tahini and tahini halva, bakery goods, and its oil, which is used to support the fragrance, cosmetics, and soap industries (Najafi et al., 2022; İncekara, 1972; Tan, 2011).

Ranked among the most cultivated plants globally, sesame's attributes include a short growing period (90-120 days), low soil selectivity, minimal water and nutrient requirements, and resilience to heat and drought. Its ease of cultivation, coupled with negligible marketing challenges, positions sesame as a viable and resilient crop (Tan, 2007). Despite its high oil content, sesame has not assumed a prominent role as an oil raw material due to its comparatively low seed yield. Recognizing its diverse applications and economic potential, there is a growing call to develop and expand sesame agriculture, particularly in our country, aiming to secure a self-sufficient source of sesame as an edible oil. Sesame remains an indispensable product in Turkey, extensively used in the production of tahini, tahini halva, flour-based, and sugary foods (Özcan, 1993).

In Turkey, sesame finds predominant consumption as tahini and halva, with additional applications in cakes, confectionery, dessert-making, bread, and bagels. Sesame oil, enriched with calcium, potassium, phosphorus, vitamin B, iron, vitamin E, and minerals, holds considerable nutritional value, extending its application beyond culinary purposes. Its diverse applications include skincare, haircare, and massage oils, showcasing brightening and revitalizing properties. Sesame oil's absorption by the skin, providing elasticity and softness, positions it as one of the best massage oils. Its applications range from preventing fungal infections to direct application to hair roots and nails. Additionally, it serves purposes in laxative regimens and diabetes management, with the stems finding utility as fuel (İncekara, 1972; İlisulu, 1973; Tan, 2012).

This chapter aims to provide an academically rigorous exploration of sesame, encompassing its historical significance, nutritional attributes, and the potential for economic development through expanded cultivation. The multifaceted nature of sesame positions it as not only a dietary staple but also a valuable resource with far-reaching implications across various industries and applications.

HISTORICAL ORIGINS, AGRICULTURAL DISSEMINATION, AND NUTRITIONAL SIGNIFICANCE OF SESAME (*SESAMUM INDICUM L.)*

Sesame (Sesamum indicum L.) holds a venerable position in botanical taxonomy, with its first formal classification attributed to Linnaeus in 1751. According to Taşkın (1997)'s research, Sesamum indicum belongs to the Tubiflorae order's Pedaliaceae family taxonomy. Rooted in Indian origins, sesame boasts an esteemed status in Hindu legends, symbolizing immortality within the cultural narrative (Agosa, 2011).

Historical Dissemination

The transcontinental dissemination of sesame seeds unfolds through historical epochs. Sesame found its way to the Americas from Africa during the 17th century (Agosa, 2011) and concurrently became integrated into the European oil industry in the 1840s (Özcan, 1993). While acknowledging the ancient presence of sesame in Anatolia, the first documented evidence of its existence within the Ottoman Empire emerges in the Ceride-i Havadis newspaper from October 1850. This documentation pertains to a list of seeds intended for dispatch to the London exhibition of 1851. Contemporary applications of sesame span traditional and industrial domains, featuring prominently in decorative roles in various culinary products, oils, body massage formulations, and margarine production.

Culinary and Industrial Utilization

Sesame seeds serve ornamental purposes in a myriad of consumables such as bread, hamburgers, bagels, pretzels, biscuits, cookies, snacks, and chocolates. Beyond culinary applications, sesame oil extends its utility to body massage, instant soup formulations, and margarine production. The incorporation of roasted sesame seeds in Far Eastern and Middle Eastern cuisines contributes to the creation of diverse sauces and condiments, including zahtar, gomasio, and shichimi togarashi. In Middle Eastern countries, sesame-derived tahini features prominently in traditional dishes such as hummus, babagannuj, salads, and desserts. Locally, tahini is consumed by blending it with grape or mulberry molasses. Sesame oil, besides its culinary applications, serves as a solvent in pesticides and intramuscular injections, while sesame meal finds consideration as animal feed or a feed ingredient (Elleuch et al., 2011).

Agricultural Significance

Sesame cultivation in Turkey is primarily concentrated in provinces such as Antalya, Muğla, Manisa, Mersin, Şanlıurfa, and Uşak. The crop is grown as the first or second crop or in mixed cultivation with other plants in the Mediterranean, Aegean, Marmara, and Southeastern Anatolia Regions (Şahan, 2020). Notably, Manavgat sesame distinguishes itself with superior quality and nutritional value, finding extensive application in the production of tahini, tahini halva, and various pastry products. These sesame-derived products are rich in protein, calcium, iron, and B vitamins, contributing significantly to both consumption and industrial utilization. The high nutritional value extends beyond the seeds to include sesame oil, sesame pulp, and shells (Onur, 2017).

Environmental Requirements and Growth Conditions

Sesame, characterized as a thermophilic plant, thrives in regions featuring tropical, subtropical, and temperate climates with elevated temperatures. Its developmental period of 90-120 days necessitates a monthly average temperature above 20 ºC, with a soil temperature of 12-15 ºC during seed germination, reaching an optimum of 20-25 ºC. Vulnerable to damage from rain and dry winds during germination, sesame exhibits sensitivity to temperature differentials between day and night, potentially leading to a prolonged developmental period (Oplinger et al., 1990). While not excessively selective regarding soil conditions, sesame manifests optimal growth in well-drained, medium-textured, organic matter-rich, sandy-clayey, and alluvial light soils (Tan, 2007). Notably, salt stress imposes detrimental effects on sesame growth, evident in decreased root and stem growth (dry weight), diminished plant height, and reduced leaf formation (Oplinger et al., 1990).

This academic exploration aims to provide a comprehensive understanding of sesame, encompassing its historical origins, agricultural dissemination, and nutritional significance, shedding light on its diverse applications across various domains.

Nutritional Components of Sesame

Approximately 75% of sesame seeds comprise oil and protein, while the remaining 25% is composed of soluble simple sugars, starch, fiber, ash, and minor components such as lignans, polyphenols, tocopherols, and sterols. Tocopherols are known to be strong natural fat-soluble antioxidants that enhance the oil's antioxidant power and nutritional worth as vitamin E through ingredients like sesamin and sesamolin (İncekara, 1972).

Sesamol, sesaminol, and sesamolinol are found in tiny levels in sesame oil, and because of the phenolic hydroxyl groups they contain, they function as extremely potent antioxidants. Sesamin, sesamolin, sesangolin, and 2-episalatin, lacking a phenolic function, do not exhibit antioxidant effects. However, if sesamin undergoes metabolism in the body with one or more compounds containing phenolic groups, it may manifest antioxidant effects in vivo. Furthermore, during the refining and roasting procedures, sesamolin transforms into sesamol and sesaminoline, which increase the oil's antioxidant antion (Bozkurt, 2006).

Sesame oil, esteemed for its nutritional content, resistance to oxidative deterioration, and pleasing taste and aroma, has been regarded as a valuable oil since ancient times (Elleuch et al., 2007). The light-yellow color of raw sesame oil distinguishes it from the slightly darker, more pronounced taste of roasted sesame oil (Elleuch et al., 2011). Furthermore, sesame exhibits a higher oil content compared to all other oilseeds (Uzun et al., 2007). Comprising approximately 80% unsaturated fatty acids, predominantly oleic and linoleic acid, sesame oil maintains a liquid state at room temperature (Akinoso et al., 2010).

The oil and fatty acid content of sesame seeds vary based on the varieties grown in different regions globally (El-Khior et al., 2007). The quality of vegetable oils is intricately linked to their fatty acid composition, which determines their suitability for edible or industrial purposes. The proportions of acids such as palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid play a crucial role in defining the quality of vegetable oils. Oleic acid and linoleic acid, constituting around 83% of the total, are particularly significant for the oil's quality. Sesame oil also contains certain fatty acids such as lauric acid, myristic acid, palmitoleic acid, arachidic acid, behenic acid, and euric acid, as well as saturated fatty acids like palmitic and stearic acid (Bayder and Turgut, 1999; Latif and Anwar, 2011).

Sesame and its derivatives exhibit superiority over other oilseeds, with sesame oil being notably resistant to oxidative rancidity compared to commonly used vegetable oils. This resistance is attributed to the presence of tocopherols and distinctive lignans such as sesamol and sesamolinol. As a result, sesame oil can be effectively used by incorporating oils such as soybean and sunflower to mitigate lipid oxidation (Liu et al., 2011). Some studies even propose that, in terms of nutritional value, sesame oil stands as the best oil after olive oil and can be a suitable substitute for the latter (Borchani et al., 2010).

Vegetable proteins assume a crucial role in human nutrition, particularly in regions with suboptimal average protein intake. The ongoing exploration of plants as new protein sources for functional food ingredients and nutritional supplements reflects the growing global interest in vegetable protein products (Khalid et al., 2003). With the aim of addressing protein deficiency and seeking alternatives to milk and meat proteins, plant proteins and oilseed proteins are increasingly recommended as substitutes for animal proteins (Lopez et al., 2003). Beyond being the oilseed with the highest oil content, sesame shares similarities with high-protein products like almonds (20% protein) and hazelnuts (21% protein), further emphasizing its role as a valuable protein source ranging from 20-25% protein content (Cano-Medina et al., 2011). The residual sesame meal, containing 50% protein after oil extraction, also emerges as a noteworthy protein source for functional food ingredients and nutritional supplements (Achouri et al., 2012). To effectively contribute to food applications, plant proteins must possess functional properties, including essential amino acids (Schieberle, 1996; Khalid et al., 2003). Sesame protein, while insufficient in lysine and isolosine, proves adequate in amino acids such as valine, sulfur-containing methionine, and tryptophan. The distinctive high methionine content sets sesame apart from other oilseeds. Although lysine content falls slightly below the FAO recommendations for children, it remains sufficient for adult consumption. Overall, essential amino acids are reported to meet the requirements for all consumer types (Cano-Medina et al., 2011; Xu-Yan et al., 2012).

In addition to its culinary application as a cooking oil, sesame oil functions as a flavor enhancer in Chinese, Korean, and Southeast Asian cuisine. Sesame oil quality, which is crucial for consumer approval, is mostly defined by its scent, which is a complex blend of many flavor components. This aroma varies across sesame varieties and different processing parameters, including heat treatment conditions and the extraction process. Changes in the concentration of volatile components have a notable effect on the flavor of roasted sesame oil (Xu-Yan et al., 2012). Distinct flavors emerge in sesame samples subjected to varying heat treatment conditions, likely attributable to differences in the thermal stability of flavor and aroma components (Schieberle, 1996).

UTILIZATION OF SESAME AND ITS BY-PRODUCTS: AN IN-DEPTH EXAMINATION

Sesame contains potential uses. It includes sesame oil, sesame pulp that is being evaluated as a by-product after oil extraction, the peeled Shell portion used to make tahini and halva, sesame sprouts, lignans extracted from sesame or its oil, and sesame leaves. Seed sprouts, recognized for their rich dietary fibers and bioactive components, are consumed as functional foods in Asian countries and have gained popularity in American and European regions. While mungbean and soybean sprouts are more prevalent, sesame seed sprouts exhibit promising attributes (Liu et al., 2011).

The ethanolic extract of sesame presents itself as a potential alternative preservative against oxidative degradation in vegetable oils. The ethanolic extract of sesame presents itself as a potential alternative preservative against oxidative degradation in vegetable oils. Sesame extracts from different seed conditions have been shown to be effective in preventing oxidative degradation in olive oil, soybean oil, sunflower oil, and corn oil (Konsoulata et al., 2010). The most effective extracts are those derived from unhulled an unroasted sesame seed. Sesamol and Brown molecules like melanoidin are responsible for the antioxidant actipn in the oil derived from roasted sesame seeds, with sesaminol being a key component (Kumazawa et al., 2003). Sesame meal, often considered a by-product and discarded or used as animal feed in some sesame-producing regions, has antioxidant properties. Research indicates that sesame meal extract can be utilized as a natural antioxidant when added to other oils, especially those rich in polyunsaturated fatty acids (Mohdaly et al., 2011).

In the production of halva and tahini, sesame seeds are peeled and separated as a by-product. Despite the lower fat and protein content of the shell fraction compared to the inner part, it exhibits higher levels of dietary fiber, ash, polyphenols, and free fatty acids (Elleuch et al., 2007). Crushed sesame, utilized in tahini and tahini halva production, stands out for its high energy content derived from its rich fat, protein, calcium, and B vitamins. The nutritional values of tahini and tahini halva surpass those of desserts made only from flour, oil, and sugar (Akinoso et al., 2010; Anon, 2010). Tahini production involves cleaning sesame by sifting or soaking in salt brine, facilitating shell separation. The resulting sesame seeds are peeled and roasted to produce tahini, a paste-like oily mixture (Döker et al., 2010).

A classic Turkish treat, tahini halva, is created by baking tahini, which is manufactured from dehulled and roasted sesame seeds, along with sugar, citric acid, tartaric acid, and chemicals derived from soapwort juice, with sesaminol being and important ingredient (Kumawaza et al., 2003). It is offered plain or flavored with walnuts, pistachios, and cocoa, known in the Western world as Turkish Honey, Turkish dessert, or Turkish halva (Bayder and Turgut, 1999). Sesame, containing approximately 56% oil, is roasted after being ground in a mortar. Tahini is produced by removing sesame oil and grinding it, it is often consumed by mixing with molasses or used in the production of tahini halva (Were et al., 2006).

Manavgat, situated in the Mediterranean region, continues its sesame culture by producing Manavgat Golden Sesame, known for its unique taste, aroma, and composition, with a geographical indication. 'Civirdik,' a dessert consumed in solid form during very cold winter months, is made from a combination of roasted sesame seeds, honey, sugar, or molasses. Despite various production methods, roasted sesame seeds and peanuts are generally mixed with heated and boiling molasses, offering a unique taste with their production methodology and preparation (Şaman and Öztürk, 2012).

THE THERAPEUTIC ATTRIBUTES AND POTENTIAL HEALTH IMPACTS OF SESAME CONSUMPTION

For millennia, sesame has been integral to human diets, purportedly conferring protection against various maladies. Numerous sources underscore the affirmative repercussions of sesame consumption, specifically its capacity to elevate gamma tocopherol levels in plasma and exhibit heightened vitamin E activity. The prevailing belief centers on its potential to thwart age-related maladies like cancer and heart disease. Studies affirm that the daily inclusion of sesame in the diet correlates with reduced cholesterol levels and heightened antioxidant capacity. Furthermore, sesame oil is posited as a deterrent against colon cancer, hypertension, and lipid peroxidation (Elleuch et al., 2011).

Accordind to Chang et al. (2002), the phenolic chemicals in the Shell fraction of sesame seed make it a poweful antioxidant that can effectively combat in vitro preoxidation system. Sesame oil enhances the protective effects of antioxidant enzymes on the brain, such as SOD, CAT, GPx, and GST.

In mice subjected to a 20% sesame oil diet for 15 days, a decrease in enzyme secretion was observed. However, this reduction is contextualized within the antioxidant-rich nature of sesame oil, conferring protection against oxidative damage due to ischemia (Chang et al., 2002).

Sesamin, a constituent of sesame and sesame oil, and its derivative episesamin, found in a 1:1 ratio in refined, unroasted sesame oil, play pivotal roles in reducing serum cholesterol, lipid levels, and blood pressure. Despite lacking synergistic effects with alpha-tocopherol, sesamin enhances the bioavailability of gamma tocopherol. Notably, in vivo DNA tests Show that both sesamin and episesamin have no genotoxicity and poor radical scavenging activity (Hori et al., 2011). Sesamin, additionally, showcases a protective effect against hypertension and hormone-related diseases, such as breast cancer (Hata et al., 2010). Sesame oil encompasses diverse physiological functions, including estrogenic activity, lipid, and arachidonic acid level reduction (Chang et al., 2002).

The roasting process of sesame seeds is a pivotal determinant of sesame oil's color, composition, and quality. Roasting conditions have an impact on antioxidant components that are essential for stability; the best antioxidant compounds and total phenolic content are abtained 200 °C for 20 minutes (Jannat et al., 2010). The antioxidant properties of defatted sesame flour are attributed to sesaminol glycosides, showcasing the significance of plant glycosides in sesame's antioxidant profile (Kang et al., 1999).

Despite the myriad benefits associated with sesame and its products, potential adverse effects are acknowledged. Direct exposure to cosmetic and pharmaceutical products containing sesame allergens may induce skin inflammation in susceptible individuals (Eleuch et al., 2011). Sesame allergies, first identified in 1950, manifest symptoms such as urticaria, angioedema, rhinitis, and asthma, with a 14-kDa protein identified as a major allergen. Health concerns also arise from phytic acid and oxalic acid in sesame shells, particularly the latter, which constitues 5.39% of the shell and poses a risk of kidney stones due to its interaction with calcium (Chang et al., 2002). Nevertheless, it is imperative to note that products like sesame oil, tahini, and tahini halva generally mitigate these risks, given the removal of the shell fraction during production stages (Eleuch et al., 2011).

CONCLUSION

Vegetable ois have a vital role in dietary habits, underscoring their necessity in human nutrition. Following sunflower, soybean, rapeseed, and cotton in the hierarchy of vegetable oil production, sesame (Sesamum indicum L.) emerges as an industrial crop of extensive global and national utility. Predominantly featured in the production of tahini, tahini halva, and bakery products within our national context, sesame assumes a pivotal role as a primary crop, with the potential for secondary cultivation following cereals. The evaluation of sesame's industrial production capacity reveals its dual role as both a fundamental raw material and a prolific source of various end products, both domestically and globally.

The geographical indication of Manavgat Golden Sesame in our country further accentuates the strategic significance of sesame cultivation. Operating as a standalone summer crop, sesame undergoes transformation into diverse products, serving as a subject of traditional and industrial trade practices. Acknowledged for its nutritional richness, sesame earns recognition as a functional food, attributable to its positive health effects. The expansive potential of sesame, yielding products such as sesame oil, pulp, tahini, tahini halva, and traditional items, positions it as a versatile agricultural commodity.

Despite its historical prevalence, sesame has experienced a decline in production and consumption amidst evolving global conditions. Within our national borders, significant potential exists for the augmentation of oilseed plants, with specific emphasis on sesame cultivation. Recognizing the pivotal role of governmental promotion becomes imperative to expand cultivation areas and bolster productivity.

Moreover, the prominence of tahini and tahini halva in the food industry underscores the necessity of fostering increased consumption of local products. The unique attributes of Manavgat sesame, characterized by its distinct grain size and oil content, warrant heightened promotion through national and international media channels, positioning it as a notable tourism asset. Capitalizing on the regional nomenclature and engendering trust in locally recognized products can culminate in the development of preferred commodities, thereby contributing to both the rural economy and the tourism sector. The unequivocal reality remains that the strategic promotion of this distinctive product will invariably yield substantial economic contributions at both the district and national levels.

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CHAPTER IV

KOMBUCHA IN SOIL ENRICHMENT: A HOLISTIC PERSPECTIVE

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INTRODUCTION

The utilization of kombucha in agriculture represents a dynamic intersection between ancient traditions and contemporary agricultural practices. This chapter embarks on a comprehensive exploration of kombucha's multifaceted roles, delving into its definition in an academic context, unraveling the historical trajectory that intertwines cultures across centuries, and examining its diverse applications in soil enrichment, plant growth promotion, and sustainable agriculture (Fathurrohim et al., 2022, Kolo et al., 2022, Bülbül et al., 2018).

In the academic discourse surrounding kombucha, its definition emerges as a fermented beverage with a rich historical tapestry, underpinned by a symbiotic culture of bacteria and yeast (SCOBY). As we navigate through its historical trajectory, the origins in ancient China, its dissemination to Japan and Russia, and its resurgence in Europe and the United States unfold, revealing a beverage deeply entwined with health and wellness narratives (Petruzello 2023).

The subsequent exploration ventures into the contemporary landscape, where kombucha transcends its traditional libation status. Its applications extend far beyond the realm of a refreshing drink, evolving into a versatile agent in the culinary arts, mixology, skincare, and even as a botanical nutrient for plants. As kombucha's popularity burgeons, its historical roots fuse with modern trends, positioning it as a key player in the global health and wellness movement (Batista 2022, Smith 2022).

Transitioning into the heart of this academic discourse, the chapter meticulously examines the multifaceted utility of kombucha in soil enrichment. This entails a closer look at its impact on soil microbiota, nutrient availability, and solubility. The symbiotic relationship between kombucha and soil microorganisms unfolds, offering insights into how this fermented elixir can potentially revolutionize soil health and contribute to sustainable agricultural practices (Durmuş and Kızılkaya 2022, Mohd Zaini et al. 2022, Öztürk, 2022 a,b,c; Bülbül et al. 2018, Durmuş and Kızılkaya 2016, Pedraza 2016, Lukiwati et al. 2008, Saravanan et al. 2008).

The examination extends to kombucha's role in plant growth promotion, shedding light on its positive influences on crop yields, stress tolerance, and root development. As we delve into the realm of sustainability, the chapter underscores how kombucha aligns with the ethos of reduced chemical dependency, potentially transforming agricultural landscapes towards more eco-friendly and resilient systems (Fathurrohim et al. 2022, Durmuş and Kızılkaya 2022, Mohd Zaini et al. 2022, Bülbül et al. 2018, Pedraza 2016, Lukiwati et al. 2008, Saravanan et al. 2008, Shehata and El-Boroiiosy 2007, Shehata and Lila 2005).

Yet, in the pursuit of harnessing kombucha's potential, practical considerations and challenges emerge. Questions regarding application methods, quality control, and regulatory hurdles beckon further research and refinement. This introduction sets the stage for a scholarly journey into the intricate web of kombucha's influence on agriculture, acknowledging its roots, celebrating its potential, and recognizing the nuanced challenges that accompany its integration into modern farming practices.

DEFINITION OF KOMBUCHA IN ACADEMIC CONTEXT

Kombucha represents a fermented beverage derived from the infusion of sweetened tea that has undergone a transformation through fermentation, primarily facilitated by a symbiotic culture of bacteria and yeast (SCOBY). This fermentation process is characteristically extended over a period ranging from several days to several weeks, yielding a beverage notable for its slight effervescence, tangy flavor profile, and, at times, a mild alcoholic content. The pivotal agent driving this metabolic conversion is the SCOBY, an intricate gelatinous consortium of microorganisms, predominantly consisting of bacterial and yeast strains. This microbial community is responsible for converting the sugars in the sweetened tea into a variety of organic acids, such as gluconic and acetic acids, as well as trace amounts of carbon dioxide and alcohol. These metabolic processes collectively contribute to the distinct sensory attributes, flavor nuances, and carbonation characteristic of kombucha (Petruzello, 2023, Coelho et al., 2020, Dufresne and Farnworth, 2000).

Kombucha has garnered recognition for its potential health-promoting attributes, encompassing probiotic qualities believed to be conducive to supporting gastrointestinal well-being, antioxidant properties, and the presence of assorted bioactive compounds that may exert beneficial effects on overall health. Consequently, kombucha has emerged as a popular functional beverage, frequently consumed for its perceived health-enhancing properties (Petruzello, 2023, Coelho et al., 2020, Dufresne and Farnworth, 2000).

It is pertinent to note that the sensory dimensions and compositional features of kombucha exhibit variability contingent upon several influential factors. These factors encompass the choice of tea employed in the infusion, the duration of the fermentation process, and the inclusion of supplementary flavorings or ingredients during the brewing phase. Furthermore, it is conventionally characterized as a refreshing non-alcoholic beverage. However, in the case of homebrewed versions, trace amounts of alcohol can occasionally be detected due to the inherent fermentation processes (Petruzello, 2023, Coelho et al., 2020, Dufresne and Farnworth, 2000).

KOMBUCHA'S HISTORICAL TRAJECTORY

Kombucha's historical origins are veiled in antiquity, rendering the precise det”ermination of its inception a challenging endeavor. Nonetheless, a careful examination of its evolution reveals a complex tapestry interwoven with a multitude of historical and cultural contexts. This exposition seeks to provide a scholarly insight into the historical narrative of kombucha, presenting a chronological overview of its trajectory (Troitino, 2017).

Ancient China

Kombucha's provenance is often attributed to ancient China, where it bore the epithets "The Tea of Immortality" and "Divine Tea." Over two millennia ago, it is believed to have made its debut in the Chinese landscape. However, ascertaining the exact date of its discovery remains an elusive pursuit. Nevertheless, historical records suggest that it garnered reverence due to its purported health-enhancing properties.

Dissemination to Japan and Russia

The diffusion of kombucha transcended national borders and found its way to Japan, where it was referred to as "kōcha kinoko" or "red tea mushroom," and to Russia, where it assumed the moniker "Tea Kvass." In these diverse locales, the methods of preparation and brewing underwent adaptation, aligning with the idiosyncrasies of local customs and the availability of indigenous ingredients.

Europe and the Early 20th Century

The late 19th and early 20th centuries witnessed kombucha's ascendancy in Europe. During this era, it experienced a resurgence in popularity within the European tea culture, largely due to its perceived health benefits. Its association with various health attributes elevated its status as a sought-after beverage.

Kombucha's Emergence in the United States

Kombucha made its inaugural appearance in the United States during the late 20th century, a period in which it began to gain recognition as a health-promoting elixir. This era also marked the inception of homebrewing practices and the emergence of commercial production, catalyzing the growth of kombucha's presence.

The Contemporary Resurgence

In the early 21st century, kombucha experienced a revitalization, primarily driven by the burgeoning interest in health and wellness. This renaissance positioned it as a staple within health food stores and as a favored choice among individuals seeking natural, probiotic-enriched beverages.

Throughout its historical odyssey, kombucha has been intrinsically linked to an array of health-related claims and purported benefits, encompassing detoxification and immune system support, among others. These claims have significantly contributed to its enduring popularity. However, it is noteworthy that rigorous scientific research continues to investigate many of these purported benefits, and conclusive findings remain forthcoming (Petruzzello,2023).

Presently, kombucha manifests itself in an array of flavors and forms, encompassing traditional homemade brews and commercially produced iterations crafted by both small-scale artisanal breweries and prominent beverage conglomerates. This evolution positions kombucha as a notable participant in the global health and wellness movement, resonating with a diverse community of enthusiasts who appreciate its potential health merits and its distinctive sensory attributes.

THE MULTIFACED UTILITY OF KOMBUCHA

Kombucha, a fermented tea beverage renowned for its ancient origins and distinctive attributes, extends its utility well beyond a mere potable refreshment. Its versatility and growing popularity, underpinned by its unique characteristics and purported health merits, merit a closer examination. In the following discourse, we elucidate the primary areas of application for kombucha, rooted in academic scrutiny (Gtsilivingfoods, 2023; Petruzzello 2023; Fathurrohim et al., 2022; Kolo et al., 2022; Ziemlewska et al., 2022a; Ziemlewska et al., 2022b; Alboreadi et al., 2021; La Gory, 2016; Coelho et al., 2020; Kaufman, 2013, Dufresne and Farnworth 2000):

- **Beverage Consumption:** A Refreshing Libation: Foremost, kombucha emerges as a favored beverage choice. Its subtly tart and effervescent profile renders it an appealing alternative for individuals seeking respite from saccharine or carbonated counterparts.
- **Probiotic and Gut Health: Digestive Well-Being:** Kombucha stands as a bearer of live probiotic cultures, which hold the potential to foster a flourishing gut microbiome. The consumption of kombucha may serve to ameliorate digestive processes and underpin the broader realm of gastrointestinal health.
- **Health and Wellness: Potential Health Benefits:** Kombucha is intrinsically linked to an array of purported health advantages, including enhancements in immune function, augmented energy levels, and the facilitation of detoxification processes. However, it is imperative to acknowledge that scientific inquiry into these claims remains ongoing.

- **Alcohol Alternative:** A Low-Alcohol Quotient: While traditionally a non-alcoholic beverage, kombucha, particularly in homemade or small-batch iterations, may occasionally harbor trace quantities of alcohol, courtesy of the fermentation process. This attribute positions kombucha as a favorable low-alcohol substitute for other alcoholic libations.
- **Culinary Applications:** A Flavorful Ingredient: Kombucha assumes a role as a distinctive culinary seasoning, imparting its tangy and acidic nuances to a spectrum of dishes, dressings, and sauces.
- **Mixology:** Cocktail Crafting: Kombucha takes center stage in the realm of mixology, serving as a versatile component in the concoction of kombucha-based cocktails, thus infusing a novel dimension into traditional libations.
- **Skin Care:** Topical Expedience: Select individuals leverage kombucha for topical applications, applying it to the skin in pursuit of its purported skin-enhancing attributes, envisioned to refine texture and appearance.
- **Hair Care:** A Hair Rinse Elixir: Kombucha finds utility as a post-shampoo hair rinse, functioning to augment hair health and luster, with subsequent rinsing following application.
- **Vinegar Substitute:** Serving as Vinegar's Proxy: The innate acidity of kombucha renders it a suitable surrogate for vinegar in specified culinary formulations, including salad dressings and marinades.
- **Plant Fertilizer:** Botanical Nutriment: Diluted kombucha emerges as a natural, organic fertilizer, bestowing nourishment on plants, thus contributing to soil enhancement and amelioration.
- **Pet Health:** Wellness for Companion Animals: Certain pet owners advocate for the inclusion of unflavored kombucha in their pet's diet, with the intention of bolstering digestive health in their animal companions.
- **Homebrewing and Fermentation:** Catalyzing Fermentation Kombucha functions as a quintessential starter culture for diverse fermented foods and potations, endowing them with the beneficial microorganism’s requisite for the fermentation process.

- **Detox and Cleansing:** In Detoxification Regimens: Kombucha is occasionally incorporated into detox diets and cleansing protocols, wherein it is perceived as a facilitator of the body's inherent detoxification mechanisms.

It is imperative to recognize that the applicability of kombucha traverses diverse terrains contingent upon individual inclinations and cultural practices. While its myriad applications offer a tapestry of utility, the essence of kombucha remains anchored in its distinctive flavor and the potential health advantages attributed to the presence of probiotics and antioxidants. Prudence dictates the judicious consumption of kombucha, with the consultation of healthcare professionals in cases where specific health concerns arise.

KOMBUCHA IN SOIL ENRICHMENT

One of the pivotal aspects of Kombucha's role in agriculture is its potential to enrich the soil. Through its probiotic content, Kombucha can contribute to the proliferation of beneficial microorganisms in the soil. This enhanced microbial diversity is associated with improved nutrient availability for plants and can help suppress soil-borne diseases.

Kombucha and Soil Microbiota

The intricate interplay between soil microbiota and agricultural ecosystems is fundamental to sustainable crop production. In recent years, kombucha, a fermented tea beverage rich in probiotics and bioactive compounds, has garnered attention for its potential impact on soil health and microbial communities. This scholarly investigation explores the complex link between soil bacteria and kombucha, with the goal of clarifying the mechanisms and consequences of using it in agroecosystems (Durmuş and Kızılkaya, 2016; Bülbül et al., 2018).

- **Probiotic Microorganisms:** Kombucha contains lactic acid bacteria, acetic acid bacteria, and yeasts that can enrich the soil's microbial diversity. This increased microbial activity can enhance nutrient cycling and organic matter decomposition. An in-depth analysis of kombucha's microbial composition, with a focus on the various probiotic microorganisms such as Acetobacter and Brettanomyces and their potential interactions with soil microbes.

- **Microbial Diversity:** Studies have shown that Kombucha-treated soils exhibit greater microbial diversity. This diversity can contribute to improved soil health by increasing its resilience to environmental stressors.
- **Bioactive Compounds:** Evaluation of the bioactive compounds present in kombucha, such as organic acids, antioxidants, and vitamins, and their influence on soil microbial communities.

Nutrient Availability and Solubility

Soil nutrient availability and solubility play pivotal roles in determining plant health, crop productivity, and overall agricultural sustainability. In recent years, kombucha, a fermented tea beverage, has emerged as a potential agent for modifying these critical soil attributes. Kombucha's organic acids, such as acetic acid and, gluconic acid, vitamins, minerals, and bioactive compounds, can influence nutrient availability and solubility in the soil (Durmuş and Kızılkaya 2022, Mohd Zaini et al. 2022, Pedraza 2016, Lukiwati et al. 2008, Saravanan et al. 2008).

- **Nutrient Availability:** Kombucha's application to soil may result in increased availability of essential nutrients, such as nitrogen, phosphorus, and micronutrients, to support plant growth.
- **Nutrient Solubilization**: Organic acids in Kombucha can chelate or solubilize essential nutrients, making them more available for plant uptake. This can lead to improved nutrient utilization by crops. On the other hand, probiotic microorganisms from kombucha may stimulate soil microbial activity, leading to enhanced nutrient mineralization and cycling.
- **Reduction in Synthetic Fertilizer Use:** Enhanced nutrient availability may reduce the need for synthetic fertilizers, reducing the environmental impact associated with their production and application.

Mechanisms of Interaction:

Following the application of kombucha, diverse mechanisms may manifest in the soil (Durmuş and Kızılkaya, 2022; Mohd Zaini et al., 2022; Bülbül et al., 2018; Durmuş and Kızılkaya, 2016; Pedraza, 2016; Lukiwati et al., 2008; Saravanan et al., 2008).

- **Microbial Competition and Synergy:** Probiotic microorganisms in kombucha may compete or cooperate with indigenous soil microbes, impacting overall microbial community structure and function.
- **Nutrient Dynamics:** Kombucha's introduction to soil ecosystems may influence nutrient availability, cycling, and the potential for improved plant nutrient uptake.
- **Chelation of Nutrients:** Investigation into the capacity of kombucha's organic acids to chelate minerals in the soil, rendering them more soluble and accessible to plants.

Implications for Soil Health and Agriculture

It is not surprising that kombucha, given its microbial interactive potency and richness in minerals, emerges as a noteworthy alternative for soil health and fertility, as cited for numerous reasons. (Durmuş and Kızılkaya, 2022; Zaini et al., 2022, Bülbül et al., 2018; Pedraza, 2016; Lukiwati et al., 2008; Saravanan et al., 2008; Shehata and El-Boroiiosy, 2007; Shehata and Lila 2005).

- **Enhanced Soil Fertility:** A detailed analysis of kombucha's role in soil fertility enhancement through improved microbial diversity, nutrient provision, and pathogen suppression.
- **Pathogen Suppression:** Kombucha's antimicrobial properties may help suppress harmful pathogens in the soil, potentially reducing the incidence of soil-borne diseases in crops.
- **Sustainable Agriculture Practices:** Discussion of how the integration of kombucha in agriculture aligns with sustainable farming practices, potentially reducing the need for chemical inputs.

KOMBUCHA FOR PLANT GROWTH PROMOTION

Research has indicated that Kombucha can positively influence plant growth and development. Its application can lead to several beneficial outcomes for agricultural crops (Fathurrohim et al., 2022; Durmuş and Kızılkaya, 2022; Mohd Zaini et al., 2022; Bülbül et al., 2018; Pedraza 2016; Lukiwati et al., 2008, Saravanan et al., 2008; Shehata and El-Boroiiosy, 2007; Shehata and Lila, 2005)

- **Increased Yields:** Kombucha's nutrient-enhancing effects can result in higher crop yields. Plants provided with a nutrient-rich environment are more likely to produce larger and healthier yields.
- **Stress Tolerance:** Kombucha-treated plants have demonstrated enhanced stress tolerance. This can be particularly beneficial in regions with adverse environmental conditions, such as drought or salinity.
- **Root Development**: Kombucha's influence on root development is noteworthy. Enhanced root growth contributes to increased nutrient absorption and overall plant health.

SUSTAINABILITY AND REDUCED CHEMICAL DEPENDENCY

The application of Kombucha in agriculture aligns with the growing emphasis on sustainable farming practices. Its ability to improve soil health, reduce the need for synthetic chemicals, and enhance plant resilience makes it a valuable component of sustainable agriculture (Durmuş and Kızılkaya, 2022; Durmuş and Kızıklaya, 2016; Fathurrohim et al., 2022; Bülbül et al., 2018; Lukiwati 2008; Shehata and El-Boroiiosy, 2007).

- **Chemical Reduction:** Kombucha's capacity to enhance soil quality and suppress diseases can potentially reduce the reliance on synthetic pesticides and fertilizers, thereby diminishing the environmental impact of agricultural practices.

- **Water Conservation**: Kombucha's ability to enhance nutrient availability and improve soil structure can reduce water usage in agriculture, particularly in water-scarce regions.

PRACTICAL CONSIDERATIONS AND CHALLENGES

While the potential benefits of Kombucha in agriculture are promising, several practical considerations and challenges must be acknowledged:

- **Application Methods:** Determining the most effective application methods and concentrations for Kombucha in agriculture is an ongoing challenge. Research is needed to optimize these factors.
- **Quality Control**: Ensuring the quality and consistency of Kombucha used in agriculture is essential. Quality control measures are necessary to prevent variations in microbial content.
- **Regulatory Hurdles:** The use of Kombucha in agriculture may be subject to regulatory constraints. Clear guidelines and regulations need to be established for its application.

CONCLUSION

In drawing the threads of this academic exploration together, the journey through kombucha's diverse roles in agriculture reveals a narrative rich in history, promise, and challenges. The definition of kombucha, as explored in the introductory sections, encapsulates its essence as a fermented beverage, but it becomes evident that kombucha is more than a drink; it is a conduit for symbiotic relationships between microorganisms, cultures, and the environment.

The historical trajectory of kombucha, from ancient China to the contemporary health and wellness movement, unveils a narrative of adaptability and cultural diffusion. Kombucha's resurgence in the modern era aligns with the growing awareness of health-conscious consumers, creating a bridge between tradition and the zeitgeist of wellness.

As we traverse the chapters on soil enrichment, plant growth promotion, and sustainability, kombucha emerges as a potential catalyst for transformative agricultural practices. Its impact on soil microbiota and nutrient dynamics, along with its ability to enhance plant growth and reduce chemical dependency, positions it as a key player in sustainable farming dialogues.

However, the journey is not without its challenges. Practical considerations, such as application methods, quality control, and regulatory frameworks, beckon further exploration and refinement. The path to fully harnessing kombucha's potential in agriculture requires interdisciplinary collaboration, rigorous research, and a holistic understanding of its intricate interactions within ecosystems.

In conclusion, the discourse on kombucha in agriculture invites scholars, practitioners, and enthusiasts to engage in a nuanced dialogue that extends beyond the boundaries of a fermented beverage. Kombucha's journey in agriculture mirrors the symbiosis it embodies –a harmonious collaboration between ancient wisdom and contemporary innovation. As this chapter closes, the potential for kombucha to contribute to sustainable agriculture remains an open question, inviting further inquiry, experimentation, and the collective wisdom of those who seek to cultivate a healthier, more resilient agricultural landscape.

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CHAPTER V

EXPLORING THE DUALITY OF ENTEROCOCCI: A COMPREHENSIVE EXAMINATION OF THEIR POTENTIAL IN FOOD APPLICATIONS AND ASSOCIATED PATHOGENICITY

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INTRODUCTION

A balanced diet, encompassing the requisite daily nutritional components, is essential for sustaining the body's energy and health. The escalating consumption of fermented foods, particularly milk and dairy products, is emblematic of efforts to fulfill these nutritional requirements. In response to consumer demands, diverse food varieties are being developed, each subjected to production processes designed to enhance their physical, chemical, and microbiological attributes. This optimization aims to prolong the shelf life of foods, imbue them with functional properties, and introduce distinctive features through the incorporation of various food additives, which may be either synthetic or semi-synthetic. Notably, there has been a discernible shift towards the utilization of natural food additives in recent years, aligning with the burgeoning consumer preference for healthier and naturally derived products in tandem with industrial advancements (Öztürk, 2022).

The paramount concern for food safety emanates from the prevalence of foodborne diseases that have inflicted considerable morbidity and mortality globally over the years. The ingestion of foods infected by microorganisms and the poisons produced by specific microbes are invariably associated with these diseases. A contemporary trend involves an increasing proclivity for the consumption of foods that positively modulate biological functions, thereby mitigating the risk of pathogenic microbial proliferation and associated diseases. Probiotics, categorized as live microorganism cultures conferring beneficial effects when ingested in sufficient quantities, have gained prominence in this context. Notably, probiotics, encompassing lactic acid bacteria of the genera *Lactobacillus*, *Bifidobacterium*, *Enterococcus*, and *Streptococcus* have been associated with a spectrum of advantageous properties, including anticancer, antimutagenic, and antioxidant activities (Graham et al., 2020; Öztürk, 2022).

Enterococci are a type of microbe that are classified as gram-positive, non-spore forming, oxidase-negative, facultative anaerobic, and catalase-negative bacteria. They are usually seen in single, double, or chained cocci. Thriving in diverse habitats and demonstrating adaptability, enterococci contribute to the nutritional value of foods through the production of metabolites such as microbial enzymes and bacteriocins. Their synthesis of natural antimicrobial compounds and potential applicability as probiotics have garnered considerable research attention. Nevertheless, the adoption of *Enterococcus* species as probiotics remains contentious due to the concurrent acknowledgment of their virulence factors, including cytolysin, aggregation factor, gelatinase, sex pheromones, enterococcal surface adhesins, and hyaluronidase. Noteworthy concerns include heightened antibiotic and multi-antibiotic resistance, as well as clinical implications for diverse infections such as meningitis, respiratory system infections, endocarditis, and intra-abdominal and pelvic infections in humans. Cases of biofilm infections, bacteremias, wound and tissue infections, newborn sepsis, and urinary tract infections highlight concerns about the prudent use of enterococci as probiotics. Despite these challenges, a pressing need exists for comprehensive investigations into the virulence factors governing the plausible use of enterococci as probiotics (Graham et al., 2020; Oruç et al., 2021; Öztürk, 2022).

HISTORICAL OVERVIEW AND GENERAL FEATURES OF ENTEROCOCCI: AN ACADEMIC PERSPECTIVE

The taxonomic history of Enterococci has been elucidated through the endeavors of various researchers, with the initial nomenclature, "Gram-positive diplococcus of intestinal origin," being ascribed by Thiercelin in 1899. The designation "enterococcus" was introduced by Thiercelin in the same year, characterizing this bacterium as an intestinal commensal with inherent pathogenic potential (Garcia-Solanche and Rice, 2019). The nomenclature "*Enterococcus*" was formally instituted by Thiercelin and Jouhaud in 1903. However, in 1906, Adrewes and Horder challenged Thiercelin's genus definition, identifying St. Faecalis, isolated from a patient with endocarditis, and noting its pathogenic attributes and propensity to form short and long chains. Subsequent challenges in classification arose due to a dearth of phenotypic information, resulting in confusion with other Gram-positive, catalase-negative cocci-like bacterial genera, particularly *Streptococcus*, casting an ambiguous light on enterococcal taxonomy (Oruç et al., 2021).

Nevertheless, distinctive features, such as the ability of most *Enterococcus* species to thrive at temperatures ranging from 10 to 45 °C, develop within a pH range of 4 to 9.6, tolerate 6.5% NaCl, survive at 40% bile concentration, and withstand heat treatment at 60 °C for 30 minutes, serve to differentiate enterococci from other Gram-positive, catalase-negative cocci. Additionally, enterococci exhibit characteristics of being oxidase-negative, non-spore-forming facultative anaerobes, and typically occur in chains or pairs, belonging to the *Enterococcaceae* family. Recent developments, notably Lancefield's serological typing system introduced in 1933, which identified group D antigens of fecal origin, led to the reclassification of enterococci as "Lancefield's group D is streptococci." Sherman's subsequent taxonomic scheme in 1937 further refined this classification into four groups: pyogenic, viridans, lactic, and enterococci (Öztürk, 2022).

A pivotal advancement in 1984 by Shleiter and Klipper-Balz delineated St. faecalis and St. faecium as constituents of the newly defined genus *Enterococcus*. This seminal reclassification, based on DNA: DNA and DNA: rRNA hybridization studies, demonstrated a genetic affiliation of St. faecalis and St. faecium with non-enterococcal streptococci within serological group D. Further chemotaxonomic and phylogenetic studies by Shleiter and Klipper-Balz in 1984 disclosed that streptococci should be encompassed within the *Enterococcus* genus, revealing 58 distinct species (Graham et al., 2020; Yazıcı, 2020). Molecular analyses to date have identified nearly 69 enterococcus species, encompassing those adhering to the *Enterococcus* genus but lacking several phenotypic features characteristic of this genus (Işık, 2020).

Despite the historical elucidation of enterococcal taxonomy, the phylogenetic system of the *Enterococcus* genus remains incompletely unraveled. Recent discoveries, such as the isolation of novel species including *E. alcedinis, E. oliuce*, and *E. bulliens* by Jin et al. in 2017, *and E. wangshanyvanii* and *E. crotali* by McLauglin et al., underscore the dynamic nature of the *Enterococcus* genus. This dynamism suggests that the genus has not been exhaustively explored, with the potential for the discovery of additional diverse species in future research endeavors (Ben Braiek and Smaoui, 2019; Graham et al., 2020; Öztürk, 2022).

TAXONOMIC CLASSIFICATION AND GENERAL CHARACTERISTICS OF ENTEROCOCCI

Taxonomically, Enterococci are classified within the Bacteria Kingdom, Firmicutes Phylum, Bacilli Class, Lactobacillales Order, Enterococcaceae Family, and Enterococcus Genus. In 2009, Ludwig et al. proposed the grouping of *Enterococcus, Vagococcus, Tetragenococcus,* and *Melissococcus* under the *Enterococcaceae* family based on their 16S rRNA gene similarities, highlighting the medical and economic significance of this taxonomic classification (Aktuğran, 2019; Oruç, 2019; Yazıcı, 2020; Dapkevicius et al., 2021; Oruç et al., 2021).

Morphologically, *Enterococci* are Gram-positive, cocci-shaped, ovoid, non-spore-forming, catalase-negative, oxidase-negative, and typically found in short and double chains (Bouymajane et al., 2018; Fard et al., 2019; Graham et al., 2020; Özkan et al., 2021; Turner et al., 2021). Colonies with a diameter of 1-2 mm develop after 24 hours of incubation on sheep or rabbit blood agar, and they exhibit viability upon prolonged storage at -70 °C in a medium containing 10% glycerol, with some variants observed to be even smaller in size (Özkök, 2018).

Enterococci are chemo-organotrophic facultative anaerobes with homofermentative metabolism, culminating in lactic acid production as the product of carbohydrate fermentation. While various selective media are employed for the isolation and identification of Enterococci, specific biochemical tests for this purpose are yet to be defined. Nevertheless, enterococci manifest distinctive traits, including tolerance to 6.5% NaCl, resistance to 40% bile salt, esculin hydrolysis, growth in the presence of up to 0.4% sodium azide, inability to produce gas from glucose, and differentiation from the *Leuconostoc* genus. Additionally, Enterococci exhibit the capability to metabolize sugars such as β-glucosidase, leucine arylamidase, D-fructose, galactose, β-gentiobiose, glucose, lactose, maltose, D-mannose, ribose, trehalose, cellobiose, and N-acetylglucosamine, yielding acid, glycolysis, methyl-β-D-glucoside, amigdrin, and arbutin.

Enterococci generally exhibit urease negativity and an inability to produce acid from D-arabinose, erythritol, D and L-fructose, methyl α-D-xylose, and L-xylose. Remarkably, these bacteria demonstrate resilience against external environmental conditions and physical and chemical factors. They thrive in both aerobic and anaerobic environments, encompassing a broad temperature range (10-45 °C) with an optimum at 35 °C, displaying adaptability to hypotonic and hypertonic conditions and reproducing across a wide pH range (pH 4.6-9.9). Features distinguishing *Enterococci* from *Streptococci* include survival after 30 minutes of heating at 60 °C and the ability to grow in an environment supplemented with 40% bile salts (Ben Braiek and Smaoui, 2019; Dapkevicius et al., 2021; Samani et al., 2021; Soleimani-Delfan et al., 2021; Tsanasidou et al., 2021; Öztürk, 2022).

Enterococcus species, constituting the third-largest group within the Lactic Acid Bacteria (LAB) category, encompass nearly 69 subspecies, as evidenced by recent research (Camara et al., 2020; Graham et al., 2020; Chen et al., 2021). Predominantly, *E. faecalis* and *E. faecium,* ubiquitous in various environments, including food sources, are among the most commonly isolated *Enterococcus* species (Graham et al., 2020). Noteworthy in the classification of LABs is the distinctive position of *Enterococcus*, forming a separate group from other LAB genera due to its dual role as both pathogenic and commensal bacteria (Dinçer and Kıvanç, 2021). The nutritional exigencies of enterococci are intricate, requiring various amino acids and B-group vitamins for their development and growth, thereby facilitating their isolation from diverse environments (Graham et al., 2020).

Enterococcus bacteria, integral to clinical and food microbiology, are ubiquitously distributed in nature, spanning the digestive tracts of healthy humans and animals, commensal niches in the urogenital region, soil, water, sewage, aquatic environments, and plants (Ben Braiek and Smaoui, 2019). Additionally, they are prevalent in various food products such as milk, meat, and fermented vegetables. While enterococci are not inherently highly pathogenic, they are implicated in a majority of hospital-acquired infections. *E. faecalis* and *E. faecium* are the primary causative agents of enterococcal infections in humans, leading to nosocomial infections, severe blood tract infections, endocarditis, septicemia, meningitis, peritonitis, bacteremia, burns, postoperative infections, abdominal and biliary tract infections, pelvic infections, catheter infections, and infections associated with medical implant devices (Garcia-Solache and Rice, 2019; Dapkevicius et al., 2021).

Studies on infectious agents underscore the significance of enterococci as the third most common cause of infective endocarditis, following *S. aureus* and viridans Streptococci. Notably, the infectious properties and pathogenicity of enterococci are perceived negatively due to their association with diverse infections (Samani et al., 2021). Apart from *E. faecium* and *E. faecalis*, approximately 24.6% of all *Enterococcal* infections are attributed to other *Enterococcal* species. Species such as *E. casseliflavus, E. gallinarum, E. mavis, E. hirae, E. mundtii, E. avium, and E. raffinosus* have been linked to post-treatment hematological malignancies, neutropenia, and infections in individuals undergoing corticosteroid treatments. Notably, *E. durans, E. hirae,* and *E. mundtii*, belonging to the *E. faecium* species group, exhibit elevated pathogenic capacities, sharing common ancestry (Laukova et al., 2021).

The pathogenicity of enterococci stems from their possession of virulence properties, genetically encoded determinants that confer pathogenic effects through resistance or adhesion to the defense mechanisms of other microorganisms. While the complete understanding of the virulence mechanisms of enterococci remains elusive, recent studies have uncovered the presence of virulence determinants in enterococci isolates, elucidating their role in the etiology of diseases. Advances in detection techniques have facilitated the identification of these virulence factors in both clinically derived enterococci and strains isolated from food sources (Graham et al., 2020).

Numerous therapeutic modalities are employed in addressing infectious enterococci, reflecting the imperative need for antimicrobial interventions in both human and animal contexts. Antibiotics and bacteriocins represent key agents in the therapeutic armamentarium against infectious enterococci. The ubiquity of antibiotic usage has, however, precipitated the emergence of antibiotic resistance profiles among microorganisms, including enterococci. Certain *Enterococcus* isolates exhibit tolerance to the bactericidal activity of diverse antibiotics, leading to the loss of efficacy through single or multiple resistance mechanisms, thereby conferring resistance to antimicrobial agents

(Margalho et al., 2020). A pivotal challenge in the treatment of enterococcal infections lies in their intrinsic or acquired resistance to employed antimicrobials. Acquired resistance mechanisms endow bacteria with newfound resilience, exacerbating the challenges associated with treatment and facilitating the transfer of resistance genes (Dapkevicius et al., 2021). The dual challenge of virulence factors and antibiotic resistance underscores the complex nature of enterococcal infections, although enterococci also exhibit positive effects on both food and living organisms (Garcia-Solache and Rice, 2019).

Fermentation, as one of the oldest and most economically prudent methods of food preservation, has been integral to human dietary practices since the transition to settled life. Fermented foods and beverages, derived from raw materials such as milk, meat, grains, and vegetables, are produced through the metabolic activities of microorganisms and the enzymatic pathways of raw materials (Margalho et al., 2020). Lactic acid bacteria (LAB), utilized in food fermentations since ancient times, play a crucial role in this process. LAB, including enterococci, contribute to the preservation of food by producing lactic acid, acetic acid, aroma compounds, bacteriocins, hydrogen peroxide (H_2O_2), diacetyl, ethanol, exopolysaccharides, and other inhibitory enzymes during fermentation. These components not only mitigate the risk of contamination by potent pathogens but also alter the sensory and textural properties of the final product, enhancing its microbial quality and shelf life (Graham et al., 2020).

Enterococci, as lactic acid-producing bacteria, are a prominent component of LAB and are frequently encountered in traditional food products. These bacteria, adept at adaptation to food conditions such as salt content and pH, naturally occur in diverse food items. Enterococci, together with LAB, contribute significantly to the improvement of microbial safety, extension of shelf life, and enhancement of taste and aroma in food products through processes like proteolysis, lipolysis, and glycolysis (Dinçer and Kıvanç, 2021). While chemical preservatives have traditionally been employed to control microbial contamination and food spoilage, consumer preferences are shifting toward perceptions that such additives may pose health risks. Consequently, there is an increasing interest in the development of effective and natural food preservatives to align with evolving consumer perceptions (Ye et al., 2021). Furthermore, enterococci-produced bacteriocins, referred to as enterocins, exhibit antimicrobial activity against a spectrum of pathogens, underscoring their potential as natural agents for food preservation (Bellei et al., 2018).

The intestinal microbiota constitutes a vast and intricate assembly of microbial communities, harboring myriad bacterial species within the human body. This complex ecosystem, teeming with trillions of microorganisms, plays multifaceted roles crucial to the host, encompassing protection against enteropathogens, contribution to normal immune functions, and extraction of carbohydrates and nutrients from the diet (Kusuma et al., 2019). Among the extensively studied entities as potential probiotics within this milieu are enterococci. Probiotics, defined as living microorganisms conferring health benefits when consumed in sufficient quantities, have prompted intensive investigation into the probiotic potential of enterococci, which are inherent components of the natural microflora in the gastrointestinal tracts of both humans and animals, actively participating in digestive processes and posited as prospective contributors to probiotic functionality (Motey et al., 2021; Graham et al., 2020).

The consideration of enterococci as probiotics, however, has become a subject of contention owing to factors such as their inherent pathogenicity marked by virulence factor determinants, antibiotic resistance, and challenges associated with their full integration into food systems. Notably, the absence of recognition in the Generally Recognized as Safe (GRAS) status and the exclusion from the Qualified Presumption of Safety (QPS) list further contribute to a negative perception regarding the probiotic attributes of enterococci. Despite these concerns, the significant role of enterococci in food systems cannot be overlooked, and their evaluation in various fermented food samples has been documented. Addressing the divergence in opinions on the probiotic potential of enterococci necessitates a comprehensive approach involving the isolation and enrichment of diverse strains through rigorous screening processes. This imperative is underscored by the understanding that a broader array of well-characterized strains is requisite for the enhanced utilization of enterococci as probiotic cultures in both food systems and human applications (Shi et al., 2020).

ENTEROCOCCI IN CULINARY APPLICATIONS: AN EXAMINATION OF THEIR PRESENCE AND ROLE IN FOOD MICROBIOLOGY

Enterococci, encompassing a diverse group of microorganisms capable of thriving in various environments such as soil, water, sewage, surface water, plants, and constituting a common component of both human and animal microbiota, hold significance in the context of food microbiology (Ben Braiek and Smooui, 2019; Graham et al., 2020). Among the numerous species within the *Enterococcus* genus, *E. faecalis* and *E. faecium* emerge as particularly noteworthy. *E. faecalis* predominates in the enterococcal microflora of the gastrointestinal tract, while *E. faecium, E. mavis,* and *E. hira*e assert dominance in the intestinal flora (Ben Braiek and Smaoui, 2019; Graham et al., 2020).

As members of the Lactic Acid Bacteria (LAB), enterococci, known for their resilience to pasteurization and thermization temperatures, naturally occur in a wide array of foods, including dairy products, meat, seafood, and fermented vegetables. Their adaptability to diverse components and growth conditions allows them to persist in both raw materials and processed foods, thereby significantly contributing to the microbiota of fermented foods (Graham et al., 2020; Dinçer and Kıvanç, 2021; Öztürk, 2022). In traditional food production, enterococci play pivotal roles as starter cultures or co-starter cultures during the ripening periods of various food products (Graham et al., 2020).

Despite their historical utilization in food production, enterococci have recently garnered attention due to concerns regarding their pathogenic properties. Virulence determinants identified in various enterococci strains have led to their exclusion from the Generally Recognized as Safe (GRAS) status and the Qualified Presumption of Safety (QPS) list, necessitating stringent safety evaluations by the European Food Safety Authority (EFSA) for each strain's approval and use in any application (Margalho et al., 2020; Dapkevicius et al., 2021; Dinçer and Kıvanç, 2021).

Inherent to their potential pathogenicity, select species and strains of enterococci manifest health-promoting attributes and confer technological benefits within the food industry. Beyond their involvement in enzymatic processes and acidification, enterococci substantially contribute to the sensory aspects of aroma, flavor, texture, and overall organoleptic properties-of various food products. The production of bacteriocins by enterococci not only extends the shelf life of foods but also underscores their pivotal role in industrial microbiology. Notably, enterococci, exhibiting proteolytic, lipolytic, and esterolytic activities, are pivotal in fermenting citrate and generating diverse aroma components. This renders enterococci indispensable as natural starter or co-starter cultures, particularly in the production of fermented meat and dairy products, synergistically operating with other LABs (Ben Braiek and Smaoui, 2019; Graham et al., 2020; Dinçer and Kıvanç, 2021).

The majority of Enterococcus strains deemed suitable for deployment as starter cultures contribute positively to the enhancement of organoleptic properties in fermented foods, encompassing meat, dairy, and vegetable products. Despite the potential negative impact of certain species as opportunistic pathogens, the incorporation of enterococci in foods, either as starter or co-starter cultures, remains prevalent. As co-starter cultures, enterococci, with their robust acid production potential, significantly augment the compositional attributes of the starter cultures. Supplementary cultures are typically introduced to ameliorate organoleptic properties and hasten ripening, with enterococci serving a dual role as auxiliary cultures and functional probiotics within food systems. Research has underscored the functionality of enterococci in fermented products, designating certain enterococcal species for utilization as starter/semi-starter cultures in European fermented products (Graham et al., 2020; Tsanasidou et al., 2021; Öztürk, 2022).

Numerous studies have been conducted to investigate the presence of enterococci in fermented foods and elucidate their role in shaping the structure, texture, and organoleptic properties of dairy products, meat products, fermented fruits and vegetables, and traditional fermented foods. Notably, enterococci contribute significantly to the food industry by generating aromatic compounds, including lactic acid, diacetyl, and bacteriocins, thereby influencing the structural attributes of fermented products. Moreover, there is a growing body of research on the utilization of enterococci as starter or co-starter cultures (Graham et al., 2020; Oruç et al., 2021; Özkan et al., 2021).

The historical prevalence of enterococci in milk has conventionally been linked to fecal contamination; however, contemporary research challenges this association, revealing enterococci's capacity to adapt to diverse substrates and growth conditions. Enterococci represent ubiquitous microorganisms, finding presence in both raw and pasteurized milk from various animal sources, including cows, buffalos, sheep, goats, and camels. Strains such as *E. faecalis, E. faecium, E. casseliflavus, E. hirae, E. avium, E. lactis*, and *E. italicus* have been isolated from raw milk. These species, along with E. faecalis, E. faecium, E. mavis, E. casseliflavus, and E. lactis, are also identified in cheeses derived from either raw or pasteurized milk, significantly impacting production and ripening conditions. *Enterococcus* spp., through their proteolytic, lipolytic, and esterolytic activities, citrate degradation, and the production of diacetyl and volatile compounds, play a pivotal role in imparting distinctive taste, aroma, and texture to milk and dairy products, particularly cheeses (Ben Braiek and Smaoui, 2019; Laukova et al., 2021; Öztürk, 2022).

Enterococci, exhibiting adept adaptation to cheese-specific conditions such as salt content and pH, are frequently encountered in various artisanal cheeses. Potential sources of enterococci encompass raw milk, udder surfaces, milk environments, milking equipment, and cheese workers involved in the production of raw milk-derived cheeses (Camara et al., 2020). Moreover, in numerous traditional dairy products, the presence of enterococci has been recognized, leading to their utilization as adjunct starter cultures in yogurt production due to their functional properties (Graham et al., 2020; Öztürk, 2022).

Various cheeses produced from both raw and pasteurized milk often contain non-starter lactic acid bacteria (LAB). Predominant among the *Enterococcus* species identified in food products are *E. faecium, E. faecalis*, and *E. durans. Enterococcus* strains play pivotal roles as starter and co-starter cultures in cheeses like Feta, Cheddar, Mozzarella, Pecorino, and Veneca. Furthermore, enterococci contribute significantly to the ripening process of diverse cheeses through their proteolytic, amylolytic, lipolytic, enterolytic, and citrate degradation activities. In the cheese-making process, caseins undergo partial breakdown into peptides, further hydrolyzing into amino acids. This transformation, resulting in the production of acids, alcohols, and aldehydes, particularly aromatic and branched-chain amino acids and methionine, critically influences the development of taste and aroma in cheese. Lipolysis, playing a crucial role in the synthesis of taste precursors, leads to the conversion of triglycerides into free fatty acids, subsequently forming methylketones, secondary alcohols, esters, and lactones. Additionally, citrate metabolism generates compounds such as diacetyl, acetoin, acetaldehyde, 2-3 butenediol, nitrogen, and other volatile compounds, contributing to the ultimate taste and odor characteristics of dairy products. CO_2 production may also impact the texture of certain cheeses. Numerous studies highlight the utilization of enterococci in traditional cheeses, emphasizing the beneficial and safe properties of enterococci isolated from these products (Graham et al., 2020; Margalho et al., 2020; Cenci-Goga et al., 2021; Oruç et al., 2021; Özkan et al., 2021; Öztürk, 2022).

Chajęcka-Wierzchowska et al. (2019) identified *E. faecium* (53.4%) and *E. faecalis* (34.4%) among 320 strains isolated from 182 fermented milk products in Poland. Nawaz et al. (2019) isolated *E. mundtii* QAUEM2808 from artisanal fermented milk product, Dahi, evaluating its proteolytic, cellulolytic, and amylolytic enzyme activitie, and acidification abilities, suggesting its potential as an adjunct starter culture post-safety assessment. Yerlikaya and Akbulut (2019) explored the application of *Enterococcus* species from raw milk and traditional dairy products as co-starters in Izmir tulum cheese, identifying *E. faecium* and *E. durans* among the species. Cwikova and Franke (2020) reported the frequent occurrence of enterococci, particularly in cheeses and raw milk within traditional fermented products. Enterococci's presence in traditional cheeses across Mediterranean countries and Western Europe highlights their resilience to pasteurization temperatures. Various studies conducted in Italy and Spain isolated and identified *Enterococcus* strains in different cheeses, emphasizing the prevalence of *E. faecalis and E. faecium*. In a study by Özdemir and Tsanasidou et al. (2021), the limited growth of enterococci in certain cheeses, such as Feta and curd cheeses ripened in brine, was attributed to their sensitivity to lactic acid. Overall, dairy enterococci have been acknowledged for their contribution to the taste and aroma of mature traditional cheeses, primarily through their proteolytic activity.

Numerous studies have investigated the presence of Enterococci in meat and meat products, revealing their positive contributions to the textural and organoleptic properties of fermented food products. Additionally, enterococci are acknowledged for their capacity to produce diverse aroma components, exhibit probiotic roles, and generate bacteriocins, and antimicrobial peptide components. These findings are evident in studies conducted by various researchers, including Jahansepas et al. (2020), Dinçer and Kıvanç (2021), Laukova et al. (2021), and Ye et al. (2021). Meat and meat products, constituting a crucial aspect of human nutrition, provide a nutrient-rich environment conducive to the proliferation of both pathogenic and undesirable microorganisms (Graham et al., 2020). Researchers consistently report the presence of enterococci in raw meat and fermented meat products, where they are employed as starters or co-starters to confer specific product characteristics. In fermented sausage and sausage processes, the glycolytic, proteolytic, and lipolytic activities of enterococci contribute significantly to product aroma. The incorporation of enterococci during the ripening of fermented products plays a vital role in enhancing sensor properties (Petrovic et al., 2020).

The prevalence of enterococci, particularly in animal-derived foods, is often associated with their presence in the gastrointestinal systems of animals. Enterococci are frequently isolated in meat and meat products contaminated with feces, a consequence of suboptimal hygiene practices. While enterococci are integral to the common microflora of the animal gastrointestinal tract, their occurrence in meat during slaughter is established. However, the presence of enterococci in foods does not exclusively correlate with fecal contamination, as they can also be indirectly introduced through the external surfaces of animals and contaminated water sources. Consequently, fecal contamination does not serve as a direct mode of transmission for the presence of enterococci in meat and meat products. *Enterococci* species identified in meat and meat products commonly include *E. faecium, E. faecalis, E. mundtii, E. mavis, E. casseliflavus, E. gilvus*, and *E. hirae* (Ben Braiek and Smaoui, 2019; Graham et al., 2020). Yalçın's (2018) study isolated 32 *Enterococcus* strains with high levels of aminoglycoside resistance (YSAD) from chicken meat samples, with *E. faecium, E. faecalis, E. durans*, and *E. casseliflavus* among the identified strains. Zommiti et al. (2018) evaluated the safety capacities and probiotic properties of *E. faecium* strains isolated from Kuru Ossban, an artisanal dried Tunisian meat. AlKalbani et al. (2019) reported 13 *Enterococcus* spp. isolates from fermented sausage, with *E. faecium, E. faecalis*, and *E. durans* identified among them. Dowdell et al. (2020) reported the isolation of *E. faecium* from Thai fermented sausage, displaying antimicrobial activity. Petrovic et al. (2020) isolated 21 *E. faecium* strains from fermented sausage in southeastern Serbia, assessing their probiotic properties. Dinçer and Kıvanç (2021) explored the potential probiotic nature of *E. faecium* isolates from Turkish pastrami. Kim et al. (2021) conducted a comprehensive study, isolating 572 *E. faecium* and 910 *E. faecalis* strains from cattle, pigs, and chickens between 2010 and 2019.

In plants, the presence of enterococci, whether endogenous or due to environmental contamination, is well-established. Fermented vegetables, such as soy, sorghum, and olives, commonly harbor *E. faecium* and *E. faecalis* (Ben Braiek and Smaoui, 2019; Öztürk, 2022). Plant-associated enterococcal species include *E. faecium, E. faecalis, E. mundtii, E. casseliflavus*, and *E. sulfurous* (Hanchi et al., 2018). Fard et al. (2019) isolated vancomycin-resistant enterococci (VRE) from dried vegetables in Tehran, Iran. Li and Gu (2019) identified new *Enterococcus* species from traditional Chinese pickle juice, including *E. deviesei, E. viikkiensis, E. pseudoavium, E. xiangfangensis, E. avium, E. malodoratus, E. raffinosus*, and *E. gilvus.*

Enterococcus species, exhibiting tolerance to high salt concentrations, can be isolated from beach sand, marine, and aquatic environments (Hanchi et al., 2018; Laukova et al., 2019; Graham et al., 2020). Studies indicate the isolation of several enterococcus species, including *E. mundtii, E. faecium*, and *E. durans*, from different parts of fish, such as internal organs and skin. The prevalence of Enterococci in seafood is reported to be lower than in raw or fermented fish, with common strains including *E. faecium, E. faecalis, E. casseliflavus*, and *E. hirae*. Fresh shrimps, categorized under seafood, have been reported to harbor *E. faecium, E. faecalis, E. lactis, E. casseliflavus,* and *E. gallinarum* strains in multiple studies (Ben Braiek and Smaoui, 2019; Öztürk, 2022). Biswas et al. (2019) isolated 38 *E. faecalis* strains from fermented fish samples obtained from southeastern Indian markets.

CONCLUSION

With advancing technology, the heightened emphasis on food safety has become increasingly significant. Employing controlled microflora or antibacterial agents the potential to ensure prolonged shelf life and secure food production. Lactic acid bacteria (LAB) or their byproducts, such as bacteriocins, serve as inhibitors against pathogens in food production, owing to their inherent safety and natural origin. As Enterococci, pervasive microorganisms, naturally occur in numerous food products. Numerous studies extol the advantageous effects of enterocin-producing Enterococcus strains, leveraging their roles as starters, co-starters, protective cultures, or probiotics. Nonetheless, the limited adoption of enterococci as probiotics or feed additives stems from safety concerns associated with their pathogenic attributes. As opportunistic microorganisms, enterococci possess the potential to induce severe infections and diseases, owing to their virulence factors and antibiotic resistance genes.

While reports on illnesses stemming from probiotic enterococci currently available on the market, such as *E. faecium* SF68 and *E. faecalis* Symbiofor, are absent, underscoring the safety of these enterococcal strains, it remains imperative to meticulously characterize and evaluate enterococcal strains for safety considerations in their prospective use as probiotics. In this regard, the application of contemporary scientific techniques, an updated understanding of enterococci and their properties, and adherence to pertinent guidelines and legislation are strongly advocated to discern between pathogenic and benign enterococcal strains.

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CHAPTER VI

AN IN-DEPTH ANALYSIS OF BOKASHI COMPOST: HISTORICAL EVOLUTION, METHODOLOGICAL INSIGHTS, AND RESEARCH FINDINGS IN THE CONTEXT OF SUSTAINABILITY

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INTRODUCTION

Bokashi composting is an innovative, eco-friendly, and sustainable practice that has garnered increasing attention in recent years. It resonates with the broader sustainability agenda, primarily by addressing waste reduction, nutrient recycling, soil quality enhancement, and offering an environmentally conscious approach to waste management and agriculture. Bokashi composting exhibits its relevance and applicability at the household, community, and agricultural levels, rendering it an essential tool in the pursuit of a more sustainable and resilient future (Hillberg, 2020; Footer, 2014).

Among its foremost contributions to a sustainable future is its capacity to significantly diminish the volume of organic waste directed to landfills and incinerators. This diversion from conventional disposal methods serves to alleviate the environmental repercussions associated with waste management. By recycling kitchen scraps and other organic materials, Bokashi composting mitigates the burden on waste management infrastructure and mitigates methane emissions from landfills. Crucially, owing to the anaerobic nature of Bokashi composting, it generates fewer greenhouse gas emissions when compared with traditional aerobic composting practices. The absence of oxygen in Bokashi containers results in reduced carbon dioxide release, a major greenhouse gas, during the decomposition process (Duque,2022; Hillberg, 2020; Lew et al., 2021; Kinnunen, 2017; Footer, 2014).

Furthermore, Bokashi composting effectively transforms organic waste into a valuable resource. The fermented Bokashi material is replete with essential nutrients and beneficial microorganisms, thereby enriching the soil with organic matter. This enrichment enhances water retention, nutrient availability, and overall soil health. Soils fortified with Bokashi compost necessitate reduced irrigation, thereby contributing to water conservation—particularly salient in regions grappling with water scarcity and drought conditions. Additionally, by fostering improved soil fertility and plant health, Bokashi composting curtails the demand for synthetic chemicals, including pesticides and herbicides. Consequently, this reduction in chemical application leads to a decline in chemical pollution and lends support to organic and sustainable agricultural practices (Duque, 2022; Hillberg, 2020; Lew et al., 2021; Kinnunen, 2017; Footer, 2014).

Moreover, Bokashi composting facilitates urban and small-scale agriculture, ensuring that city dwellers become active contributors to the process of food production rather than passive consumers. Its compact nature enables urban residents to engage in sustainable waste management and gardening endeavors, effectively fostering sustainability in urban settings. Given its adaptability to small spaces, community-wide implementation becomes feasible, thus fostering a shared sense of responsibility and cooperation. Community-based composting initiatives further serve to fortify social bonds, boost sustainability awareness, and promote education in sustainable practices. Furthermore, Bokashi composting encourages local food production by ameliorating soil fertility. By reducing the necessity for long-distance food transportation, this approach mitigates the associated carbon footprint, thereby substantiating its role in promoting local and sustainable food systems (Hillberg, 2020; Kinnunen, 2017; Lind, 2014).

In summation, Bokashi composting inspires both individuals and communities to adopt more sustainable lifestyles, thus engendering waste reduction, resource conservation, and fostering a deeper connection with the environment.

FROM PAST TO FUTURE

Bokashi composting represents a relatively recent addition to the compendium of organic waste management techniques, with its origins dating back to Japan in the early 1980s. The historical backdrop of Bokashi composting is intimately linked to the pioneering work of Dr. Teruo Higa, a horticulturist and professor at the University of the Ryukyus in Okinawa, Japan. Dr. Higa is credited with formulating a mixture of beneficial microorganisms, termed "Effective Microorganisms" or "EM," as a means to bolster agricultural productivity while concurrently curtailing the use of chemical fertilizers and pesticides. Dr. Higa's belief in the pivotal role of beneficial microorganisms led to the development of a fermentation technology capable of decomposing organic matter and restraining the proliferation of harmful pathogens and putrefactive bacteria. This pioneering technology laid the foundation for what later came to be recognized as Bokashi composting (EMRO, 2016; Higa, 1993).

The concept of Bokashi composting, encompassing the fermentation of organic waste, such as kitchen scraps and garden refuse, employing EM or analogous microbial cultures, was introduced by Dr. Higa. The term "Bokashi" itself is Japanese and signifies "fermented organic matter." Owing to its efficacy in organic waste management and the production of nutrient-rich soil amendments, Bokashi composting gained rapid popularity in Japan. Its reception was especially favorable in urban areas grappling with space constraints impeding traditional composting practices (EMRO, 2016; Higa, 1993).

Over time, the appeal of Bokashi composting transcended Japan's borders, permeating various countries as the public came to recognize its merits concerning waste reduction, soil enrichment, and the formulation of nutrient-dense soil amendments. Consequently, commercial Bokashi bran and inoculant products were introduced, simplifying the adoption of this composting methodology by individuals and businesses. Distinct variations of the Bokashi method and branded products emerged in response to its popularity. Bokashi composting also became an integral component of wider sustainability and waste management strategies, aligning seamlessly with the burgeoning global awareness of environmental concerns and the imperative for eco-friendly waste management solutions (EMRO, 2016; Footer, 2014).

Bokashi composting has a long history, and it continues because of ongoing research and development efforts to improve the process and investigate its use in a variety of settings, such as urban agriculture and neighborhood-based waste management program. Presently, Bokashi composting remains a favored and efficient means of managing organic waste, especially in regions constrained by space or where sustainability is a paramount concern ((Awang and Awang, 2021; Lew et al., 2021; Soto-Aquino et al., 2021; Ghanem et al., 2017; Pontin et al., 2003)

The future of Bokashi composting is imbued with promise as a growing number of individuals acknowledge its contribution to sustainable waste management and soil enhancement. As apprehension concerning the ecological footprint of waste disposal escalates, more people are actively seeking eco-friendly alternatives. Urbanization's upward trajectory renders Bokashi a pragmatic solution for addressing kitchen scraps and organic waste. With sustainable agriculture gaining momentum, Bokashi composting stands poised to become an invaluable tool for optimizing crop yields and decreasing reliance on synthetic fertilizers (Hillberg 2020, Olle 2020, Turner 2014, Footer 2014). The imperative of nutrient recycling is steadily amplifying as the global community seeks sustainable resolutions to food production and resource conservation. In this context, Bokashi composting may assume a critical role in substantiating circular economy practices ((Celestino et al., 2022; Marcello, 2021; Olle, 2021; Paes et al., 2019).

Advancements in composting technology are anticipated to make Bokashi composting more user-friendly and efficient. This evolution may encompass enhanced Bokashi containers and, potentially, the automation of the composting process (Figure1) (Lew, 2021; Kucbel et al., 2019). Various municipalities may opt to incorporate Bokashi composting into their waste management portfolios, providing residents with Bokashi bins and collection services akin to conventional waste collection programs (Lew, 2021; Machado, 2020; Epelde et al., 2018, Maso, 2008). Bokashi composting's integration into community gardening initiatives and educational programs, catering to individuals of all ages, fosters a culture of environmental responsibility and self-sufficiency.

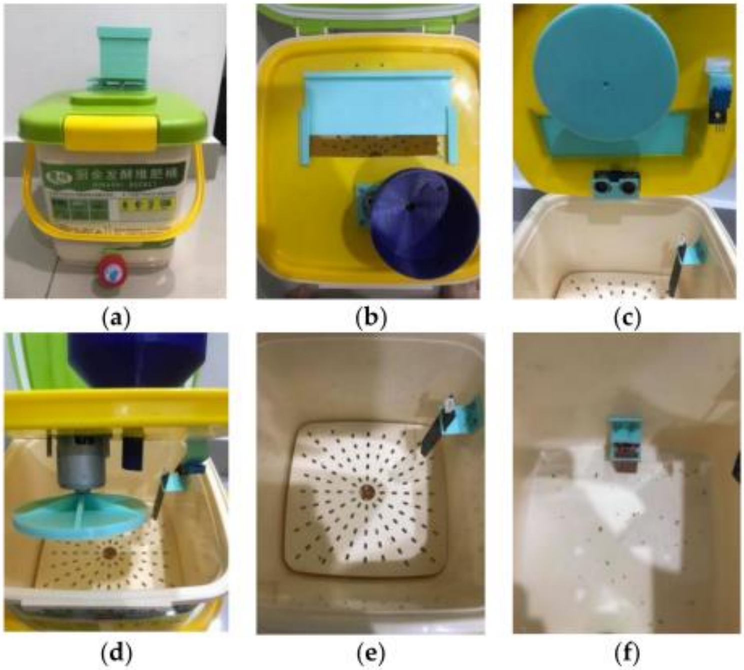

Figure 1: The elements comprising the smart composting bin are (a) the exterior of the smart composting bin; (b) a Cover placed on top of the composting bin; (c) an ultrasonic sensor, along with a temperature and humidity sensor, located on the rear side of the cover; (d) a DC motor and spindle affixed to the cover; and (e) a soil moisture sensor attached to the wall of the composting bin. (f) a water level sensor affixed to the bottom of the composting bin. (Lew, 2021).

The relentless pursuit of knowledge and innovation in the field of Bokashi composting, encompassing microbiological communities, nutrient retention, and compost quality, will further its development and refinement. Bokashi composting has already gained prominence in numerous regions globally, a trend anticipated to persist and expand to areas where it is not yet commonplace. Consequently, the future of Bokashi composting is replete with potential and assures an enduring role in sustainable waste management and soil enrichment practices.

THE METHOD OF BOKASHI COMPOSTING

Bokashi composting is a distinctive method for managing organic waste, wherein kitchen scraps, such as fruit and vegetable peels, coffee grounds, and eggshells, are combined with a specialized inoculant known as Bokashi bran. This inoculant comprises beneficial microorganisms, which are pivotal to the ensuing fermentation process. The amalgamated mixture is then deposited into a Bokashi bucket or bin, designed to create an airtight environment. This fermentation, in contrast to traditional composting, unfolds over a span of a few weeks and is notable for its absence of malodorous emissions and reduced susceptibility to pest infestations. The resultant product is not classified as traditional compost; however, it can be deployed through burial in a garden, incorporation into a conventional compost pile, or utilization as a soil conditioner. Notably, Bokashi compost is distinguished by its enrichment with beneficial microorganisms, conferring marked improvements upon soil health and fostering robust plant growth (Hillberg 2020, Footer 2014).

Materials and Equipment Required for Bokashi Composting (Hillberg 2020, Footer 2014):

- **Bokashi Bucket or Container**: Central to the Bokashi composting process is the utilization of a specialized container, commonly referred to as a Bokashi bucket or container. This receptacle is meticulously sealed to create an environment devoid of oxygen, thus facilitating the anaerobic fermentation process. A distinctive feature of this container is the inclusion of a spigot, positioned at the base, which serves the purpose of collecting the liquid byproduct produced during the fermentation process—this liquid is commonly recognized as Bokashi tea. It is noteworthy that one can procure a pre-designed Bokashi bucket from commercial sources, or alternatively, fashion a bespoke version by modifying an airtight bucket to align with the specifications of Bokashi composting.
- **Bokashi Bran or Effective Microorganisms (EM) Solution:** A fundamental component of the Bokashi composting procedure is the inoculant, which is instrumental in initiating the fermentation process. This inoculant is available in two principal forms: Bokashi bran and

Effective Microorganisms (EM) solution. Bokashi bran is the more commonplace and readily accessible variant. It serves as a carrier for the effective microorganisms, enabling their even distribution over the organic waste material within the container. An EM solution represents an alternative source of effective microorganisms, which can be administered by directly mixing it with the organic waste prior to its placement within the Bokashi container.

- **Organic Waste:** The foundation of Bokashi composting hinges upon the collection of a diverse range of organic waste materials, primarily emanating from the kitchen environment. These materials encompass, but are not limited to, fruit and vegetable peels, coffee grounds, tea bags, and assorted food waste. In addition to kitchen-derived organic waste, the scope of materials suitable for Bokashi composting extends to plant-based yard waste. This category includes items such as leaves and grass clippings, all of which can be effectively incorporated into the Bokashi composting process.

Choosing and setting up these necessary supplies and tools is essential to carrying out Bokashi composting, which is highly regarded for its ability to turn organic waste into a nutrient-rich soil conditioner via controlled fermentation.

The Sequential Steps for the Creation of Bokashi Compost (Hillberg 2020, Footer 2014):

1- **Preparation of the Bokashi Bucket:** Commence by ensuring the cleanliness and dryness of the designated Bokashi bucket or container. A pristine environment is essential for the forthcoming fermentation process. Install a drainage plate or screen at the base of the container to segregate the compost from the liquid byproduct, colloquially referred to as Bokashi tea.

2- **Stratified Application of Organic Waste and Bokashi Bran:** Initiate the process by carefully layering organic kitchen waste within the container. To expedite decomposition, the waste materials may be subjected to cutting or chopping into smaller fragments. Subsequently, administer an equitable distribution of Bokashi bran over the stratum of organic waste. If opting for an Effective

Microorganisms (EM) solution, it is advisable to amalgamate it with the organic waste prior to its placement within the container.

3- **Compaction and Iteration:** To eliminate the surplus presence of air and encourage a thorough interaction between the organic waste and Bokashi bran, employ a flat tool, such as a plate, to compact the waste materials. After that, organic waste and Bokashi bran are layered iteratively, and one layer is placed after another, with compaction applied afterward. It is paramount to allocate adequate space at the top of the container, permitting the subsequent installation of an airlock lid or seal.

4- **Hermetic Sealing of the Container:** The container is meticulously sealed, serving the pivotal purpose of establishing an anaerobic milieu, which is fundamental to the Bokashi composting process. To this end, an airtight seal or lid is employed. Some Bokashi buckets are furnished with a spigot, which serves the purpose of intermittently draining the excess liquid, commonly known as Bokashi tea. A systematic inspection and drainage protocol should be instituted to avert oversaturation.

5- **The Duration of Fermentation:** The sealed container is relocated to a cool, dimly lit locale, shielded from direct sunlight and stark temperature fluctuations. The organic waste undergoes fermentation over a duration of approximately 2 to 4 weeks. During this phase, a mild pickling or sour aroma may become perceptible, a phenomenon deemed normative.

6- **Bokashi Pre-compost**: After the fermentation process, the mixture is often referred to as "bokashi pre-compost." At this stage, the material is not fully composted, but it has undergone a fermentation process that makes it easier to break down later.

7- **Burying or Storage:** Upon the culmination of the fermentation period, the Bokashi compost material is primed for utilization. It may be interred directly within a garden, amalgamated into an exterior compost pile, or employed as a soil conditioner. In cases where immediate deployment is not a viable option, the Bokashi compost can be stored for several weeks, awaiting the opportune moment for its integration into the soil.

8- **The Waiting Period:** After the initial fermentation phase, Bokashi compost retains an acidic composition. Therefore, it is judicious to exercise restraint and await a span of a few weeks subsequent to the burial or integration with the soil prior to the commencement of planting activities.

Bokashi composting presents an effective, odorless emission-free solution for the management of kitchen waste, a particularly pertinent undertaking within constrained or urban settings. This process is characterized by its efficiency and culminates in the production of a nutrient-rich soil conditioner, significantly augmenting soil health and concurrently curtailing the quantity of waste destined for landfills.

CLASSIFICATION OF BOKASHI COMPOSTING METHODOLOGIES: AN ACADEMIC OVERVIEW

Bokashi composting, a versatile approach to organic waste recycling, encompasses a spectrum of variations and strategies. The principal types of Bokashi composting are as follows:

- **Kitchen Bokashi Composting:** This variant represents the fundamental and most prevalent form of Bokashi composting. It revolves around the collection of kitchen-generated organic waste, which includes items such as fruit and vegetable peels, coffee grounds, and other food remnants. These materials are systematically deposited within a designated Bokashi bucket, wherein they are meticulously layered with Bokashi bran or an Effective Microorganisms (EM) solution. Subsequently, the container is hermetically sealed, creating an anaerobic environment conducive to controlled fermentation. This method is particularly suitable for domestic households, encompassing urban settings (Geng, 2023; Hillberg, 2020; Footer, 2014).
- **Outdoor Bokashi Composting:** In contrast, outdoor Bokashi composting represents an upscaling of the method, tailored for outdoor application. It often involves the use of larger containers, which can include barrels or bins. This extended capacity allows for the accommodation of a broader spectrum of organic materials, extending

to yard waste. Outdoor Bokashi composting is especially well-suited for larger gardens and expanses (Geng, 2023).

- **Community Bokashi Composting:** This community-based method involves managing Bokashi composting as a group, either among people or as a community. It encompasses shared collection points and larger scale composting containers, fostering a collaborative endeavor in the management of organic waste. This method is particularly pertinent in neighborhood settings or residential complexes (Morrow and Davies, 2022; Dimock et al., 2021; Platt, 2019; Ecobin, 2016; Powel, 2013).
- **Vermi-Bokashi Composting:** This hybrid methodology integrates Bokashi compost with the influence of red wiggler worms, commonly utilized in composting. Following the initial Bokashi fermentation phase, the waste is intermixed with worm castings to further enhance the organic matter's breakdown. This amalgamation results in a compost of enhanced richness (Bokashiliving 2023, Growabundant 2023, Pérez-Godínez and Lagunes-Zarate, 2017).
- **Bucketless Bokashi Composting:** In certain variations of Bokashi composting, the requirement for a dedicated Bokashi bucket is obviated. Instead, individuals make use of their own containers or bins, relying on Bokashi bran or EM solutions to facilitate the fermentation process (Vanderlinden 2022).
- **Farming and Agricultural Bokashi Composting**: In agricultural contexts, Bokashi composting is deployed to augment soil quality and fertility. Large-scale Bokashi composting is applicable to fields and orchards, providing a consistent source of nutrient-rich soil conditioner (Lew et al., 2021; Quiroz, 2019; Epelde et al., 2018).
- **Bokashi Tea Production**: Bokashi tea, the liquid byproduct of the Bokashi composting process, is the focal point of this approach. It is produced with the express purpose of serving as a liquid fertilizer for the nourishment of plants. This technique is often employed in conjunction with other composting methodologies (Bokashiliving, 2023; Phooi et al., 2022; Olle, 2020).

- **Bokashi Toilet or Humanure Bokashi:** This specialized adaptation is tailored for the treatment of human waste, particularly in areas characterized by limited sanitation infrastructure. It plays a pivotal role in the sanitation and decomposition of human waste, rendering it safe for application in agricultural settings (Brenin et al., 2021; Brenin et al., 2019; Morrison et al., 2003).
- **Indoor and Apartment Bokashi Composting:** Bokashi composting finds particular relevance for individuals residing in apartments or constrained spaces. Specially designed indoor Bokashi bins and systems are available to facilitate the process within confined settings (Footer, 2014; Harshitha et al., 2016; Louie, 2015; Davies 2011)
- **Hybrid Bokashi Composting:** Some practitioners combine Bokashi composting with conventional composting techniques, such as aerobic composting within a compost bin or pile. This fusion of methods serves to further decompose the fermented waste and yield a more refined compost product.

The selection of a specific Bokashi composting methodology is contingent upon an array of factors, including the quantum of organic waste generated, available spatial resources, precise objectives (e.g., compost production for gardens or kitchen waste reduction), and individual preferences. Each variant of Bokashi composting is characterized by unique advantages, rendering them adaptable to diverse contexts and circumstances.

ACADEMIC INQUIRIES ON BOKASHI COMPOSTING

Within the domain of academia, an array of research endeavors has been undertaken to delve into the efficacy, advantages, and applicability of Bokashi composting in the spheres of waste management and soil enhancement. The following represent the key domains of scholarly investigation pertinent to Bokashi composting:

- **Microbial Community Analysis:** Numerous scholarly investigations have been dedicated to the systematic characterization of the microbial communities integral to the Bokashi composting process. These studies endeavor to pinpoint and evaluate the precise strains of beneficial microorganisms that orchestrate the fermentation of organic matter (Luo et al., 2022; Abo-Sido et al., 2021; Epelde et al., 2018).

- **Nutrient Content Analysis:** Bokashi compost is distinguished by its marked nutrient richness. Academic research endeavors have been conducted to gauge the nutrient levels intrinsic to Bokashi compost and to effect comparative assessments vis-à-vis traditional compost and chemical fertilizers (Lew et al., 2021; Epelde et al., 2018; Lasmini et al., 2018; Boechat et al., 2013).
- Soil Quality Improvement: A multitude of inquiries are geared towards discerning the influence of Bokashi compost on the enhancement of soil quality. Researchers conduct assessments to ascertain the manner in which Bokashi compost affects soil structure, organic matter content, and microbial diversity, culminating in amplified plant growth and vitality (Pandit et al. 2019, Urra et al. 2019, Lasmini 2018, Boechat et al. 2013).
- **Pathogen Suppression**: Bokashi composting's capacity to repress pernicious pathogens and weed seeds has invoked interest within the scholarly realm. In-depth examinations are conducted to scrutinize the repercussions of Bokashi composting on the prevalence of pathogens, along with de the potential utility of Bokashi composting for the control of agricultural diseases (Shin et al., 2017; Fontenelle et al., 2015).
- **Carbon Sequestration:** Bokashi composting presents the potential for carbon sequestration by transmuting organic waste into stable organic matter. Research efforts in this sphere delve into the capacity of Bokashi composting to mitigate climate change by dint of the attenuation of greenhouse gas emissions (Lew et al., 2021; Bosch et al., 2015).
- **Waste Management and Recycling:** Studies have been undertaken to gauge the efficacy of Bokashi composting as a means of diverting organic waste away from landfills and incineration. Scholars meticulously examine the economic and environmental advantages intrinsic to the integration of Bokashi composting within waste management systems (Agiunaga et al. 2023, Lew et al. 2021, Ecobin 2016, Freitag and Meihoefer 2000)

- **Comparative Studies:** Academic research frequently encompasses comparative investigations that adjudicate the prowess of Bokashi composting when juxtaposed with alternative composting methodologies, such as traditional aerobic composting or vermicomposting. The aim of these studies is to unravel the strengths and weaknesses of Bokashi composting across diverse scenarios (Putra et al., 2021; Ruíz-Sagasetaet al., 2019; Maso and Blasi, 2008).
- **Community and Household Adoption:** Certain research endeavors are geared towards the uptake of Bokashi composting at the level of communities and households. These inquiries traverse the social and behavioral dimensions that underpin the adoption of Bokashi composting while simultaneously elucidating the challenges and advantages experienced by practitioners (Duque, 2022; Awang and Awang, 2021; Dimock et al., 2021; Morrow and Davies, 2021; Machado and Hettiarachchi, 2020; Platt, 2019; Ghanem et al., 2017; Kinnuen 2017; Ecobin, 2016; Powel, 2013).
- **Urban Agriculture and Food Production:** The potential role of Bokashi composting within the ambit of urban agriculture and food production systems has garnered academic attention. Researchers interrogate the modalities through which Bokashi compost can be seamlessly assimilated into small-scale farming and gardening activities within urban landscapes (Duque, 2022; Bocoli et al., 2020; Hata, 2020; Olle, 2021; Olle, 2020, Platt, 2019; Lasmini et al., 2018; Quiroz ,2019).
- **Economic and Environmental Impact Assessments:** Research often embraces assessments that gauge the economic and environmental ramifications of Bokashi composting. These appraisals might encompass the conduct of life cycle assessments that serve to juxtapose Bokashi composting with alternative methods of waste management and soil amelioration (Aguinaga et al., 2023; Geng, 2023; Duque, 2022; Kinnuen, 2017, Paes et al., 2019; Ecobin, 2016; Turner, 2014; Davies, 2011; Burt, 2009; Higa, 1993).

Academic exploration in these manifold areas has served to illuminate the multifaceted dimensions of Bokashi composting, rendering it an indispensable tool in the pursuit of sustainable waste management and soil enrichment.

ANALYZING OUTCOMES IN BOKASHI COMPOSTING: AN ACADEMIC PERSPECTIVE

The academic realms dedicated to Bokashi composting have significantly contributed to the comprehension of its nuances, applications, and potential advantages within the domains of agriculture, waste management, and sustainability. The perpetuation of research endeavors endeavors to expand the breadth of knowledge surrounding this ecologically sound composting methodology.

Analyzing the results of Bokashi composting necessitates a thorough evaluation of diverse facets encompassing the attributes of the final product, its merits, and the overarching efficacy of the composting process. Several critical dimensions warrant consideration in the course of this analysis:

- **Nutrient-Rich Soil Conditioner:** A primary upshot of Bokashi composting is the formulation of a nutrient-dense soil conditioner. This compost typically boasts a substantial organic matter content, along with the retention of a noteworthy proportion of nutrients originating from the original organic waste. The scrutiny of nutrient composition within the endproduct is invaluable in ascertaining its suitability for specified horticultural or agricultural purposes (Pandit et al., 2019; Urra et al., 2019; Lasmini, 2018; Boechat et al., 2013).
- **Microbial Activity:** Effective microorganisms (EM) stand as pivotal protagonists in the realm of Bokashi composting. A dissection of microbial activity within the culminating compost can yield insights into the effectiveness of the fermentation process and the robustness of the microbial community. Microbiological assessments can reveal the presence and operational vigor of beneficial microorganisms (Luo et al., 2022; Abo-Sido et al., 2021; Epelde et al., 2018).

- **pH and Acidity:** By virtue of the fermentation process, Bokashi compost typically assumes a mildly acidic profile. The meticulous monitoring of pH levels within the ultimate compost bestows the capacity to gauge its acidity and decide on requisite adjustments prior to soil application. A preponderance of plant species flourishes within the ambit of slightly acidic to neutral pH spectra (Aguinaga, 2023; Boechat et al., 2013; Ong, 2001).
- **Odor and Appearance:** The quality of Bokashi compost can be subject to scrutiny through sensorial observations. A competently fermented Bokashi compost ought to emanate a pleasing, earthy aroma and present a dark, crumbly visage. The emergence of noxious odors or mold manifestations may serve as indicators of aberrations during the composting process (Freskayani et al., 2022; Patriani et al., 2022; Awang and Awang, 2021).
- **Moisture Content:** The assessment of moisture content in the ultimate compost stands as a pivotal determinant. Compost that is excessively saturated or excessively desiccated may warrant corrective measures to realize the optimal moisture level requisite for soil utilization (Aguinaga, 2023; Lew et al., 2021).
- **Carbon-to-Nitrogen Ratio:** The carbon-to-nitrogen (C/N) ratio holds a pivotal status in compost evaluation. A well-balanced C/N ratio within the concluding compost ascertains its capacity for decomposition and the efficacious release of nutrients into the soil. The preferred C/N ratio for mature compost usually resides between the range of 20:1 and 30:1 (Saputra et al., 2023; Lew et al., 2021; Boechat et al., 2013).
- **Pathogen and Weed Seed Reduction:** Bokashi composting's renown for the effective diminishment of pathogens and weed seeds is inherently linked to the fermentation process. The conductn of tests aimed at confirming the absence or attenuation of these undesirable entities assumes a position of prominence within the analysis (Shin et al., 2017; Fontenelle et al., 2015).

- **Plant Growth and Crop Yield:** Ultimately, the success of Bokashi composting stands amenable to appraisal via its repercussions on plant growth and crop yields. Field trials or experimental undertakings involving the application of Bokashi compost across diverse gardening or agricultural scenarios supply invaluable data concerning its efficacy as a soil conditioner and nutrient source (Bocoli et al., 2020; Hata, 2020; Olle ,2020; Quiroz, 2019; Lasmini et al., 2018).
- **Environmental Impact:** The assessment should also factor in environmental advantages, such as the mitigation of methane emissions when diverting organic waste from landfills, as an integral facet of the evaluation (Aguinaga et al., 2023; Geng, 2023; Duque, 2022; Kinnuen, 2017; Ecobin, 2016; Turner, 2014; Higa, 1993).
- **Cost-Benefit Analysis:** An economic vantage point is fundamental in the scrutiny of Bokashi composting outcomes. This encompasses the analysis of the costs attendant to Bokashi composting, spanning its initial setup and maintenance, and the alignment of these expenses against the accrued benefits, such as the amelioration of waste disposal expenses and the enhancement of soil quality. This comprehensive analysis serves to gauge the economic feasibility of the method in its entirety (Geng, 2023; Paes et al., 2019; Davies, 2011; Burt, 2009).

All things considered, the analysis of the outcomes of Bokashi composting leads to a comprehensive assessment of the characteristics of the final compost, its ability to hold onto nutrients, and its impact on plant development and the surrounding environment A regimen of periodic monitoring and meticulous testing underpins the optimization of the Bokashi composting process in alignment with its intended purpose.

CONCLUSION

Bokashi composting emerges as a pivotal and innovative ecological practice, bearing profound implications for the realms of sustainability, waste management, and agriculture. This comprehensive approach meticulously addresses the exigencies of the contemporary era, encapsulating the imperatives of waste minimization, nutrient recycling, soil amelioration, and ecologically sound waste handling.

Bokashi composting presents itself as a compelling solution, significantly diminishing the quantity of organic waste directed to landfills and incineration, thereby mitigating the pronounced environmental repercussions inherent in conventional waste disposal methods. Furthermore, this technique's intrinsic anaerobic nature affords it a unique advantage in substantially mitigating greenhouse gas emissions, notably curbing carbon dioxide release during the decomposition phase.

The byproduct of Bokashi composting, rich in essential nutrients and beneficial microorganisms, engenders a transformative effect on soil quality. It enhances the soil's capacity for water retention, augments nutrient accessibility, and fosters the overall vitality of the soil, obviating the necessity for synthetic chemicals in agricultural practices and thereby contributing to the reduction of chemical pollution. Bokashi compost, in essence, serves as a catalyst for the adoption of organic and sustainable farming practices.

The versatility of Bokashi composting is manifest in its suitability for a wide spectrum of applications, ranging from household utilization to community endeavors and large-scale agriculture. It is a pragmatic and efficient solution for the management of organic waste, encompassing urban as well as rural landscapes. Moreover, its emphasis on local food production holds significance, mitigating the environmental toll of long-distance food distribution and fostering local and sustainable food systems.

The historical trajectory of Bokashi composting, originating in Japan and subsequently garnering global recognition, underscores its relevance in diverse contextual frameworks. With technological advancements anticipated in the near future, the method stands to become even more user-friendly and efficient. Its integration into comprehensive waste management systems, community-driven initiatives, and educational programs strengthens its role as a harbinger of sustainability.

Academic exploration in the sphere of Bokashi composting has cast a beacon of understanding upon multiple facets of this practice. Scholarly pursuits have ventured into the depths of microbial communities, nutrient content analysis, soil quality enhancement, pathogen attenuation, carbon sequestration, and rigorous evaluations of economic and environmental impacts. These academic inquiries collectively illuminate the multi-faceted dimensions of Bokashi composting and underscore its potential to redefine paradigms in waste management and soil enrichment.

In summation, Bokashi composting emerges as an inspiration for both individuals and communities to embark upon the path of sustainability, leading to a reduction in waste, judicious resource employment, and a deeper, more profound connection with the environment. As the global community confronts the imperatives of sustainability, Bokashi composting assumes a central role in addressing these imperatives, offering a trajectory toward a more sustainable and resilient future.

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CHAPTER VII

SUSTAINABLE AGRICULTURE: BENEFITS AND CHALLENGES

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INTRODUCTION

The concept of organic agriculture emerged in the early 20th century as a response to growing urbanization and the widespread use of chemical fertilizers and pesticides. The organic movement originated in German and English-speaking regions and was shaped by various groups advocating for a return to rural farming practices and the utilization of organic and biological fertilizers instead of synthetic chemicals. (Lockeretz, 2007). Organic agriculture is a combination of creativity and science to protect the environment, create justice, and improve the quality of life (Pearson and Rowe, 2014).

The concept of organic agriculture

The word "organic" has various meanings, among which "(related to) organism" or more generally "(related to) living things" is more common (Khoshkhui, 2016). The first definition approved by the International Federation of Organic Agricultural Movements (IFOAM) in 2008 is “Organic agriculture is a production system that sustains the health of the soil, ecosystems, and humans. This system relies on ecological processes and biological diversity, relies on cycles adapted to local conditions, and does not depend on inputs that have problematic effects. Organic farming combines traditional, scientific, and innovative methods to take advantage of its environment, facilitate proper communication with it, and provide a good quality of life for all involved” (Khoshkhui, 2016). The second definition given by Raviv in 2010 is as follows: “Organic agriculture is the concept and method of agricultural production without the use of artificial pesticides, chemical fertilizers, as well as antibiotics and hormones in plant and animal production. Also, it has been changed to use living organisms without any genetic changes (Raviv, 2010a). Over the past four decades, organic farming and organic food have gained significant popularity in developed industrialized nations. However, proponents of industrial agriculture argue that by the early 21st century, global food production had reached unprecedented levels, and per capita food consumption in developed countries had reached a considerable amount. In 2021-2022, some underprivileged nations still grappled with hunger, and the number of food-insecure individuals has increased since 2016.

These challenges were primarily attributed to factors such as poverty, inadequate food distribution worsened by the COVID-19 pandemic, and insufficient social safety nets, rather than a shortage of food supply (Barrett, 2022). In post-war Europe, industrial agriculture drove a significant increase in food production through the widespread adoption of synthetic fertilizers and chemical pesticides, resulting in record-breaking yields. Wheat yields in the European Union-27 member states surged from 1.79 tonnes per hectare in 1961 to 4.73 tonnes per hectare in 2000 (Ritchie *et al.*, 2022). There are many definitions for organic agriculture, among which two are more comprehensive.

Perspectives on Organic Agriculture

Economy and organic agriculture

Organic farming was initially considered an abstract solution to enhance crop production in developing nations, particularly in India. Organic products tend to be more costly on the market, with, for instance, a minimum 50% price difference for organic dairy products in the United States. This price premium should serve as an incentive to reward farmers for their environmentally friendly practices and provision of nutritious food. There is a need to establish a general concept that trains organic consumers about the reasonable cost of purchasing organic products in comparison to the value of the overall well-being of a healthy diet. (Campbell *et al.*, 1998; Liyaghati *et al.*, 2010).

Biodiversity and organic agriculture

The progress of modern agriculture has a significant global threat to the gradual decreasing of agricultural biodiversity. Between 1900 and 1999, approximately 75% of the genetic diversity in agricultural plants was lost due to the widespread substitution of indigenous species with new cultivars. Worldwide breeding programs aimed at developing high-performing crop varieties often replace native ones, which exhibit high genetic diversity and adaptation to specific environmental conditions, with genetically uniform varieties that offer superior performance but are sensitive to environmental stresses. These initiatives contribute to genetic erosion, resulting in the loss of vital genes for future breeding efforts, the fading of specific species and cultivars, and the decline of indigenous knowledge (Khoshbakht and Najafi, 2010).

Plant breeding in organic farming

The Green Revolution, initiated in the 1950s, introduced high-yielding crop varieties resistant to pests and diseases, and this innovation quickly improved in developing nations. By 1990, over half of the land was dedicated to cultivation of improved wheat and rice varieties. However, this led to an increase in yield while reducing the diversity of cultivars, subsequently diminishing the crops' potential to adapt to changing environmental conditions (Mehdipour, 2010).. A fundamental pillar of organic farming revolves around the adoption of pest-and disease-resistant crop varieties. Simultaneously, in both conventional and organic farming systems, the most definitive and cost-effective method of control lies in the deployment of disease-resistant cultivars. Breeding programs typically prioritize a diverse array of resistance types, emphasizing broad-spectrum resistance and leveraging plant traits that decrease their appeal to insects, for instance. It is important to emphasize that in organic farming, the utilization of genetically modified animals, seeds, and plants is strictly prohibited (Khoshkhui, 2010).

Agriculture in organic farming

In organic agriculture, optimal crop rotations and mixed crops have special importance and place (Colla *et al.*, 2000) in different ways including minimizing plowing, or low-plough methods during land preparation. Decreasing the application of chemical fertilizers and pesticides, using an integrated management system that utilizes all elements of the surrounding environment, including animals and striving for a balanced synergy between agricultural and livestock product yields. Overcoming challenges like the high cost of animal manure and limited water for green manure plant growth is a concern for farmers. The use of urban waste and sewage sludge, known as compost, may serve as an organic fertilizer, but it faces hurdles due to its heavy metal content. To address these limitations, a practical solution for organic fertilization involves converting unwanted grasses (weeds) and plant residues into compost or liquid fertilizers during the growing season, functioning as green fertilizers (Bolandnazar, 2010). The main strategy for improving plant growth is to encourage mycorrhizal relationships in the root system, which in turn supports symbiotic bacteria that fix nitrogen in the soil as biological soil conditioners.Weed management should prioritize non-chemical and mechanical approaches, refraining from vegetation burning. Production methods should aim to safeguard the environment, protect natural resources, and maintain ecosystem equilibrium with minimum ecological disruption (Zand, 2010).

Water in organic farming

Ensuring that water supply systems remain free from harmful chemical pollutants and safeguarding the environment, human health, and animal and bird populations is of paramount importance. It is essential to prevent the accumulation of harmful substances in agricultural products and water resources, both surface and underground. It is also important to avoid using unconventional water resources such as untreated sewage effluent and polluted river water, especially for irrigating fields and vegetables. Furthermore, it is necessary to steer clear of water from downstream river areas and water tainted with nitrate compounds that can jeopardize product safety. Irrigation practices are crucial for disease management. Flood irrigation should be avoided, and irrigation should be directed away from the plant crowns. Drip irrigation is more suitable for all crops than pressurized irrigation methods. Rain irrigation is unfavorable, particularly in the case of soil-borne pathogens, such as several bacterial diseases. To suppress the spread of fungal and certain bacterial diseases, maintaining optimal soil moisture as well as greenhouse humidity control will be effective in minimizing their losses. It is worth noting that any irrigation method employed within a greenhouse, due to its enclosed environment, can rapidly elevate humidity, creating an ideal condition for the spread and contamination of different pathogens. Given the prohibition of pesticide use in organic farming, reducing greenhouse humidity through adequate ventilation and ensuring the sparse cultivation of plants can decrease pathogen activity (Khosh-Khui, 2016).

Soil in organic farming

Soil preservation and improvement represent a key facet within the framework of organic farming, providing intrinsic environmental conservation benefits (Safi et al., 2020). In the realm of organic farming, soil is regarded as a living organism. Similar to conventional agriculture, organic crops require 17 essential nutrients for optimal growth. However, in organic farming, the emphasis lies on the sources of these nutrients from non-artificial and non-chemical origins, typically based on natural, mineral, and biological sources. Consequently, the procurement of suitable organic fertilizers is a paramount concern, providing a critical foundation for the economically and scientifically sound production of organic products. Soil health constitutes a pivotal well-being component of the agricultural ecosystem. To enhance the quantity and diversity of soil organisms and maximize soil fertility, it is imperative to maintain a balance among physical, chemical, and biological factors in agricultural operations. Mycorrhizal symbiosis, also known as fungus-root, exemplifies the ecological significance of plant-fungus interactions in the soil. These associations manifest as connections between plant roots and fungi, with the majority of vascular plants engaging in such interactions. Fungal symbiosis often facilitates nutrient absorption by plants, enhances root size and longevity, protects roots from pathogens, and aids in water absorption and transport to the host plant. In arid Mediterranean regions with high calcium and pH levels, zinc and iron deficiencies are significant challenges. Lowering soil pH, which could be achieved through the application of animal manure, provides a situation for the improved absorption of these essential nutrients (Fließbach *et al.*, 2007; Asgarzadeh, 2010; Barbazán *et al.*, 2010).

Pests and diseases in organic farming

Within the realm of organic agriculture, a primary concern revolves around searching for alternative approaches to chemical control. Using integrated organic methods to combat detrimental factors stands as a key solution in organic production. This approach entails deploying various strategies, including crop diversification across different seasons, employing timely plowing techniques, incorporating suitable cover crops and green manures, and utilizing mechanical methods to manage unwanted weeds. The

main goal is to prevent the outbreak of pests, diseases, and weed distribution, thus obviating the need for chemical inputs. One of the pivotal measures in integrated pest management in organic agriculture is the utilization of healthy seeds and seedlings while avoiding the introduction of environmental stresses such as drought and salinity. Moreover, preventing root or plant organ injuries is vital against pests. Among the methods employed in pest management, biological control is the most important one. This approach involves the application of natural enemies to regulate pest and disease populations. The complexity of biological control by using living organisms could be due to both temporal and geographical factors. Success in this method depends on a thorough understanding of pest population ecology as well as the behavior and movement of both the pests and their predators. Among the pesticides used in organic agriculture, sulfur and copper-based compounds are allowed for combating fungi, while copper-based compounds and non-synthetic natural antibiotics can be used for bacterial pathogens. Heat therapy has also been demonstrated to be effective in some cases, especially in virus disease control.
Pesticides allowed in organic farming are:

Microbial pesticides: The most well-known microbial pesticide is obtained from *Bacillus thuringiensis* bacteria and can control certain types of insects.

Plant pesticides: Pesticides that plants produce from genetic materials could be added to them. For example, researchers transfer protein genes with pesticidal properties from *Bacillus thuringiensis* to plants. As a result, the plant itself produces substances that control the pest.

Biochemical pesticides: Include natural substances that interfere with plant growth, such as growth regulators, or substances that attack pests, such as pheromones.

Plant poisons: Some plants have poisonous substances against insects. These substances are extracted from plants and used on infected plants; the most important of them are pyrethrin, rotenone, and nicotine. The use of these materials is of great interest due to their fast decomposition and high efficiency in controlling the insect population. These herbal insecticides are unstable, and decompose, and become inactive after a few hours or days.

Animal husbandry and fisheries in organic farming

Organic animal husbandry aims to produce eco-friendly, high-health animals while maintaining their comfort and delivering natural-quality products. This approach necessitates adherence to organic agriculture principles. Animal feed must be 100% organic, with allowances for vitamin and mineral supplementation for dietary balance. Dairy cows, for instance, are permitted 80% organic feed for nine months, followed by a mandatory 100% organic feed for the subsequent three months. Growth hormones, enhancers, antibiotics, and similar additives are strictly prohibited in organic animal feeding. Preventative measures, such as inoculations, can be employed to maintain animal health. Organic animal husbandry practices also require that animals have access to open environments and pastures, with temporary limitations allowed for animal welfare, safety, production conditions, and environmental preservation. Birds should not be confined to cages and should enjoy natural movement in open- air conditions. Artificial insemination may be used for genetic expansion and health reasons, particularly with high-yield livestock. It is important to note that organic animal husbandry serves a niche market, appealing to consumers who prioritize product quality and health and are willing to pay premium prices. This approach may not address all the challenges in the broader livestock industry. In the context of aquaculture, organic production in both inland and seawaters prohibits the use of carcinogenic chemical compounds to prevent fish loss or water pollution (Azari Takami, 2010; Miraii Ashtiani, 2010).

Foodstuffs in organic farming

Several critical factors influencing global food quality include excessive salt and sugar content, insufficient dietary fiber, a shortage of daily fruit consumption relative to overall food intake, an inadequate supply of essential antioxidants, and the presence of residual toxins and nitrates in food. Hazardous gases, the improper use of pesticides, fungicides, and herbicides, and non-compliance with scientific standards in greenhouse production can result in products containing residual toxins for consumers. The use of drugs, antibiotics, and hormones for livestock health and growth should be based on scientific principles. It is crucial to prevent livestock from consuming fodder and seeds contaminated with harmful substances. Furthermore, the application of unprocessed animal manure in agricultural production, including vegetables, and the use of ion radiation like gamma rays for food processing and preservation should be avoided. Food storage, preparation, and processing must prioritize organic methods and avoid the use of inorganic compounds, including gases like methyl bromide and chemical additives such as antibiotics, sodium and potassium benzoate, and nitrates. Proper storage practices are essential to prevent the production of harmful substances like aflatoxins, which are pathogenic and carcinogenic, in agricultural products. Natural packaging materials should be used, while synthetic compounds and non-biodegradable materials should be avoided for packaging purposes. It is also critical to refrain from adding unnatural compounds to enhance food appearance, such as nitrates in meat products, sulfur fumes in dried fruits, and sodium bisulfite in fruit juices. The use of additives that alter the natural state of food, including preservatives, sweeteners, chemical dyes, flavorings, artificial colors, and artificial essences, should be limited. Prohibited substances in organic product processing encompass both artificial substances like isopropyl alcohol and natural substances such as petroleum solvents (Souri, 2010; Shahedi, 2010).

Organic gardening

Many horticultural productions entail substantial long-term investments. Given the perishable and fresh nature of horticultural products, their organic cultivation carries heightened significance. In light of the global shift toward organic agriculture, with an expanding organic cultivation area each year, it is anticipated that future market presence, especially in the realm of horticultural products, necessitates the supply of chemical-free organic products. In organic horticulture, the utilization of liquid manure, animal manure, compost derived from unwanted weeds between tree rows, and vermicompost is an economical and practical approach to meet the fertilizer requirements of trees. Particularly in contrast to conventional agriculture, the use of animal manure and vermicompost proves highly cost-effective in horticultural contexts. Animal manure serves as a valuable resource in organic farms and gardens, playing a vital role in enhancing the availability of essential trace elements in the soil

(Reganold *et al*., 2001; Granatstein, 2004; Ogbuchiekwe *et al*., 2004; Mon and Holland, 2005; Olgun *et al*., 2006; Raviv, 2010b).

DEBATES AND CHALLENGES OF ORGANIC AGRICULTURE

Obstacles and problems in the development of organic agriculture generally include five separate sections:

Infrastructure issues

From the perspective of the farmers polled, there are a number of apparent obstacles in this environment. These include the absence or restriction of a suitable market for organic products, the absence of a certifying body to validate the organic status of their products, insufficient storage facilities for maintaining these products, and the inadequate availability of requisite equipment for transportation and marketing. In larger markets, the availability or shortage of essential inputs for organic products also presents a challenge (Papzan and Shiri, 2012). In this context, the findings of Moschitzl *et al*. (2004), showed that the lack of an organic market, suitable agricultural policy, and social contexts can be major obstacles in the development of organic agriculture among farmers (Moschitzl *et al*., 2004). Parra Lopez (2005) attributed the reason for avoiding organic agriculture mainly to infrastructure and economic factors (Lopez and Requena, 2005).

Economic issues

Regarding economic aspects, findings based on group discussions with different farmers have revealed several challenges. These include reduced production and income when cultivating organic products, insufficient financial support for organic farming, a lack of interest among people in consuming organic materials, and a reluctance to pay higher prices for them. Additionally, farmers face obstacles such as dealers purchasing organic products at lower prices. Given that income and profit growth are significant factors in farmers' adoption of new technologies and considering that a significant proportion of farmers in various studies are in financially vulnerable or moderate circumstances, this issue emerges as one of the primary hindrances to the progress of organic agriculture among farmers (Midmore, 2001; Padel, 2001; Parra Lopez and Calatrava Requena, 2005).

The low level of information and knowledge of farmers

Insufficient information and awareness among farmers concerning organic farming, coupled with low levels of education and literacy, have significant challenges to the progress of organic agriculture within most societies. The lack of knowledge regarding the cultivation and maintenance of organic products further compounds these issues. Given the pivotal role of knowledge and information in the adoption and progress of new technologies, the lack of information and expertise emerges as a substantial constraint and a formidable barrier to the growth of organic agriculture (Wynen, 2004; Lukas and Cahn, 2008).

Technical and management issues

In this context, organic farmers confront a range of challenges. The challenges that face organic farming include managing weeds, dealing with diseases and pests, lacking technical expertise and knowledge about organic production, having limited access to suitable land for organic farming within the research area, not knowing when to plant and what kind of weather to expect for organic crop growth, not being familiar with organic farming techniques and methods, needing more stringent management and upkeep than conventional agriculture, and having a shortage of skilled labor in this field (De Buck et al., 2001; Shneeberger et al., 2002; Papzan and Shiri, 2012)….

Motivational and attitudinal barriers

Farmers' lack of enthusiasm and willingness to engage in organic crop cultivation, their entrenched use of chemicals in conventional agriculture, the allure of increased production and income through chemical use, and their perception of incompetence and lack of skills in managing organic farming collectively constitute motivational and attitudinal barriers among farmers in the context of organic agriculture development. Prior factors may also have an impact on these barriers. Despite the challenges and issues inherent in organic farming, farmers may display disinterest in cultivating organic crops and develop a negative attitude toward organic agriculture. Therefore, addressing prior issues and problems within the realm of organic farming can potentially foster a positive attitude and interest in organic crop cultivation. De Buck et al. (2001) also acknowledged the significance of sociological aspects, encompassing adoption behavior, motivational factors among organic farmers, farm characteristics, and farmers' attributes, in shaping the adoption and development of organic agriculture (De Buck *et al*., 2001; Burton *et al*., 2002; Papzan and Shiri, 2012).

CONCLUSION

Focused group conversations with organic farmers have produced a set of general recommendations for organic agriculture development, given the importance and benefits of organic agriculture for generating healthy products and supporting and growing this cultivation method. Stakeholders in the agricultural sector should consider a multifaceted approach to facilitate the export of organic agricultural products, offer support to pioneering organic farmers, initiate informative and promotional campaigns to harness the existing agricultural potential within each country, and realign agricultural research to emphasize the use of organic and biological fertilizers over their chemical counterparts. Strategic planning for agricultural research should accord special attention to organic agriculture, and an appropriate and distinct pricing system for organic products should be established to underpin the development and enhancement of this sustainable agricultural system. The provision of educational and promotional courses on organic agriculture for farmers, along with encouragement to participate in these programs, is vital. Additionally, training agricultural facilitators to disseminate knowledge of organic agriculture, coupled with promotional campaigns through mass media channels like radio, television, and other communication platforms, will contribute to raising public awareness among consumers and producers of organic products. Government bodies and organizations should extend support to organic farmers, ensuring the viability of their products, fostering the growth of local markets for organic products, conducting economic analyses, identifying global markets for exporting organic products, and establishing storage facilities with adequate cold storage capabilities. These endeavors will collectively fortify and enhance farmers' motivation and attitudes toward organic cultivation. Furthermore, providing valuable information on weed, pest, and disease management for agricultural products, as well as delivering weather-related insights to farmers via short text messages on their mobile phones from institutions and other relevant organizations, is a beneficial proposition. Such research initiatives within the agricultural domain also holds considerable promise.

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CHAPTER VIII

ORGANIC AGRICULTURE IN THE TR83 REGION

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INTRODUCTION

According to the 12th Development Plan in Türkiye, supporting environmentally friendly agricultural practices in the agricultural sector within the scope of protecting the environment and combating climate change is within the scope of policy measures to be taken in the field of agriculture and food (OG, 2023). Organic agriculture, a production method that safeguards human health and the environment, by abstaining from chemical inputs throughout production, with every stage from production to consumption being controlled and certified, plays a pivotal role in fostering a sustainable agricultural system. Türkiye is one of the largest organic suppliers in Europe, with 502 thousand hectares of organic land (MoAF, 2019). Organic agriculture in Türkiye started with the European demand season for organic raisins and dried figs, which were traditional export products in 1984-85. Over the following decade, organic farming experienced swift growth, particularly in the production of dried fruit, nuts, and cotton. The International Federation of Organic Agriculture Movements (IFOAM) stated that Türkiye with a 24% share of production, was by far the country that made the biggest contribution to the global organic cotton growth seen in the 2020-21 period (FiBL, 2023). In addition, Türkiye is an important organic exporter country, especially dried fruits, wheat, nuts, and fresh vegetables, with an export value of almost 204 million dollars and a volume of 75 thousand tons (MoAF, 2019). To capitalize on the opportunities presented by organic farming, such as contributing to environmental conservation and promoting sustainable economic and rural development, promotion policies should be implemented (Demiryürek et al., 2008).

Türkiye has great opportunities for organic farming due to its high biodiversity and soil and water structure being suitable for organic farming. The increasing need for healthy nutrition also increases the tendency towards organic products, and when evaluated from this perspective, a total increase in demand is expected (Hasdemir, 2020). The demand for organic products is increasing day by day in the world and in Türkiye. Especially during the pandemic period, the demand for reliable products, especially organic products, has increased within the framework of health-related sensitivities. Sales of organic products have increased by 30% in some countries around the world. The COVID-19 pandemic has tremendously impacted most people's purchasing behavior and has given the organic market an unprecedented upturn in many countries. Whereas food sales have increased rapidly, organic food sales have accelerated even faster around the world (FIBL, 2021; MoAF, 2021). Due to the effort to produce more food by reducing environmental risks, the importance of sustainability in the agricultural sector is increasing (Baser et al., 2017). Protecting and developing Türkiye's organic product market depends on sustainable organic agriculture production. One of the main elements that will support the sustainability of the organic agriculture sector is to increase the consumption of organic products by supporting the country's domestic market. In order for Türkiye to reach its 2030 targets and increase its organic agricultural land, it is important to evaluate its organic food chain and determine its priority needs to increase organic agricultural activities.

In Türkiye, with its favorable ecological conditions and high export potential for organic production, conducting research on organic agriculture and translating the results into practice is crucial for attaining a competitive position in the global organic market (Özyazıcı and Hanoğlu Oral, 2021). The Ministry of Agriculture and Forestry has implemented projects such as organic farming and good agricultural practices to mitigate the negative impacts of climate change (Bozoglu et al., 2019). Kayhan and Olmez (2014) argued that the initiation of organic farming practices in the Black Sea region was first applied due to the pristine quality of its water resources and natural environment, coupled with geographical constraints that limited intensive agricultural activities. The climatic and ecological conditions in the Black Sea region favor organic agriculture, offering significant potential, especially in the cultivation of widely grown crops such as tea and hazelnut (Öztürk and Dengiz, 2020). The TR83 region, situated in the Black Sea region and comprising Samsun, Tokat, Çorum and Amasya provinces, exhibits high potential for organic plant and livestock production. Hence, the aim of this study was to evaluate the current situation of organic plant and livestock production in the TR83 region.

ORGANIC AGRICULTURE IN THE WORLD

Table 1 provides the latest global data on organic agriculture. The most recent figures indicate a continuous upward trend in the number of countries engaged in organic activities, organic agricultural land, the organic share of total land, the number of producers, the organic market, and per capita consumption, reaching another all-time high. As of 2021, the number of countries with organic activities was 191, and 5 more countries were added in the last two years. Organic agricultural land covers over 76.4 million hectares in the world and Austria, Argentina and France have the largest organic areas, respectively. Even in the last two years, the world organic agricultural land has increased by 5.5%. Liechtenstein had the highest organic share, with 40.2 percent and the countries with the most significant increase in organic agriculture land were China, France, and Spain, respectively. The number of organic producers, which was 200 thousand in 1999, increased by 20% compared to 2019 and reached 3.7 million in 2021. The countries with the most producers were India (1,599,010), Uganda (404,26) and Ethiopia (218,175). The organic market size, which was 15.1 billion euros in 2000, increased by 18% compared to 2019 and reached nearly 125 billion euros in 2021.

Table 1. Organic agriculture: key indicators and top countries

Indicator	World	Top countries
Countries with organic activities	2021: 191 countries 2019: 187 countries	
Organic agricultural land (million ha)	2021: 76.4 million ha (2019: 72.3 million ha, 1999: 11 million ha)	Australia (35.7 million ha) Argentina (4.1 million ha) France (2.8 million ha)
Organic share of total agricultural land	2021: 1.6% 2019: 1.5%	Liechtenstein (40.2 %) Samoa (29.1 %) Austria (26.5 %)
Increase of organic agricultural land 2020/2021	1.3 million hectares (ha); +1.7 %	China: 319,000 ha (+13 %) France: 228,000 ha (+9 %) Spain: 198,000 ha (+8%)
Wild collection and further non-agricultural areas	2021: 29.7 million ha (1999: 4.1 million ha)	Finland (6.9 million ha) Zambia (2.5 million ha) Namibia (2.3 million ha)
Producers	2021: 3.7 million producers (2019: 3.1 million 2006: 1 million 1999: 200 000 farmers)	India (1,599,010) Uganda (404,246) Ethiopia (218,175)
Organic market	2021: 124.8 billion euros (2019: 106.4 billion euros, 2000: 15.1 billion euros)	US (48.6 billion euros) Germany (15.9 billion euros) France (12.7 billion euros)
Per capita consumption	2021: 15.7 euros 2019: 14.0 euros	Switzerland (425 euros) Denmark (384 euros) Luxembourg (313 euros)
Number of affiliates of IFOAM –Organics International	2022: 791 affiliates	Germany: 81 affiliates China: 54 affiliates India: 46 affiliates USA: 45 affiliates

Source: FiBL, 2023, based on national data sources, data from certifiers and IFOAM – Organics International

As of 2021, the global organic agricultural land covered 76.4 million hectares. Oceania, encompassing an area of 36 million hectares or nearly half of the world's organic agricultural land (47%), emerged as the region with the highest extent. Following Oceania, Europe accounted for 17.8 million hectares, Latin America for 9.9 million hectares, Asia for 6.5 million hectares, Northern America for 3.5 million hectares, and Africa for 2.7 million hectares (Figure 1).

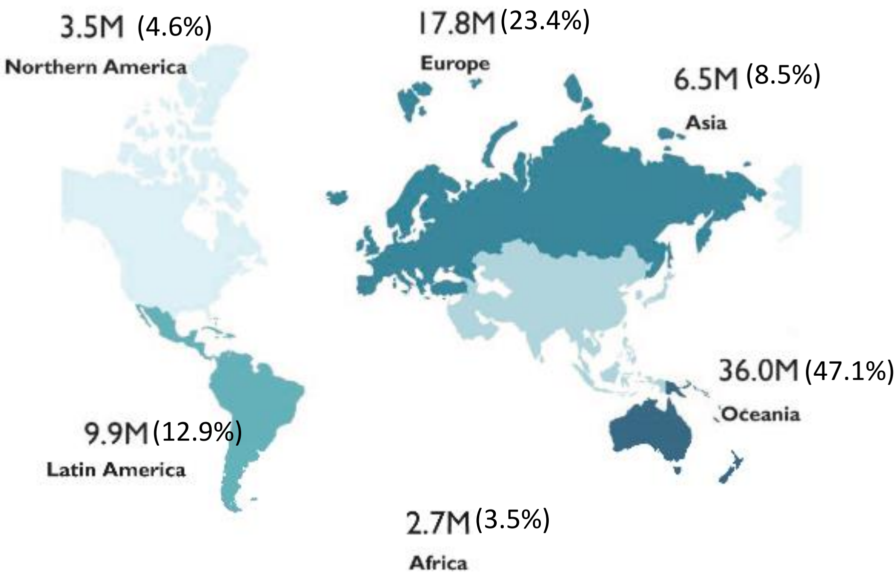

Figure 1. Organic agricultural land in 2021 (M: millions)
Source: FiBL, 2023.

Examining Figure 2, it is evident that the growth of the organic agricultural area and the share of organic agricultural land in the world are consistently increasing. Organic agricultural land, which stood at 15 million hectares in 2000, has experienced a fivefold increase, reaching 76 million hectares in 2021. On the other hand, the share of organic agricultural areas in total agricultural areas in 2021 was 1.6%.

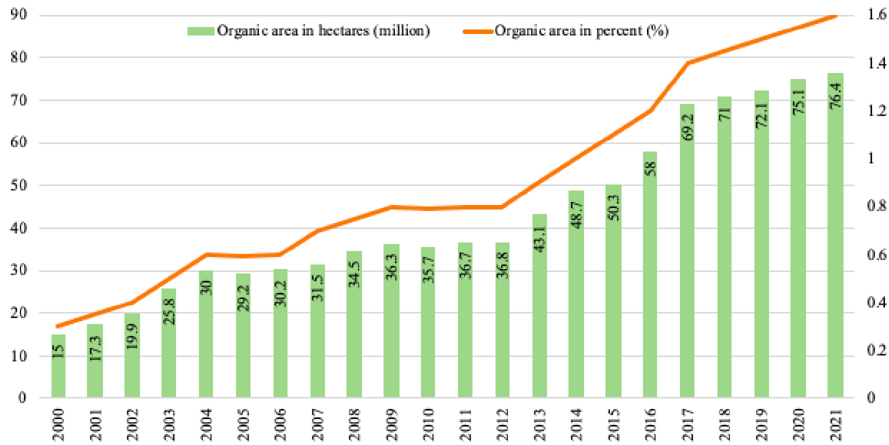

Figure 2. Development of the organic agricultural land and share of organic agricultural land between 2000 and 2021 in the World.
Source: FiBL, 2023

ORGANIC AGRICULTURE IN TÜRKIYE

Türkiye is now one of the largest global organic suppliers in Europe with a continuously increasing market share (Aydın Eryılmaz et al., 2021). According to the IFOAM Report, Türkiye is the largest organic producer with 74,545 and the third- best country in terms of top permanent crop groups such as olives, grapes and nuts in Europe (IFOAM, 2021). Table 2 gives data for the number of crops, the number of farmers and production between 2002 and 2022 in Türkiye. The number of organic producers has constantly increased and reached its maximum with approximately 80 thousand in 2018. However, the number of organic producers has decreased by almost half in the last four years. In addition, the number of crops has regularly increased over the years; the number of organic products, which was 150 in 2002, increased by 78% to 268 in 2022. There have been significant developments in the amount of organic production until 2016 and it reached 2.4 million tons in 2016. However, after this year, organic production in Türkiye has entered a decreasing trend. In 2020, organic production decreased by 20% compared to the previous year and has remained at 1.6 million tons for the last two years.

Table 2. The Development of organic agriculture in Türkiye over the years

Year	Number of crops		Number of farmers		Production	
	Number	Change (%)	Number	Change (%)	Tonnes	Change (%)
2002	150	-	12 428	-	310 125	-
2003	179	19.3	14 798	19.1	323 981	4.5
2004	174	-2.8	12 751	-13.8	377 616	16.6
2005	205	17.8	14 401	12.9	421 934	11.7
2006	203	-1.0	14 256	-1.0	458 095	8.6
2007	201	-1.0	16 276	14.2	568 128	24.0
2008	247	22.9	14 926	-8.3	530 224	-6.7
2009	212	-14.2	35 565	138.3	983 715	85.5
2010	216	1.9	42 097	18.4	1 343 737	36.6
2011	225	4.2	42 460	0.9	1 659 543	23.5
2012	204	-9.3	54 635	28.7	1 750 127	5.5
2013	213	4.4	60 797	11.3	1 620 466	-7.4
2014	208	-2.3	71 472	17.6	1 642 235	1.3
2015	197	-5.3	69 967	-2.1	1 829 291	11.4
2016	238	20.8	67 878	-3.0	2 473 600	35.2
2017	214	-10.1	75 067	10.6	2 406 606	-2.7
2018	213	-0.5	79 563	6.0	2 371 612	-1.5
2019	213	0.0	74 545	-6.3	2 030 466	-14.4
2020	235	10.3	52 590	-29.5	1 631 943	-19.6
2021	263	11.9	48 244	-8.3	1 590 086	-2.6
2022	268	1.9	44 927	-6.9	1 600 858	0.7

Source: TURKSTAT, 2022

The growth of the organic agricultural land and organic share in Türkiye between 2000 and 2021 is shown in Figure 2. The organic area experienced a steady increase, peaking at 842 thousand hectares in 2014. However, organic area decreased by 40% in 2015 compared to 2014, falling to 515 thousand hectares. Especially since 2018, there has been a significant decline in organic agriculture land. Consequently, the area allocated to organic agriculture within the total agricultural area reached its maximum in 2014 as a percentage, but in recent years, unlike the rest of the world, it has shown a decreasing trend in Türkiye.

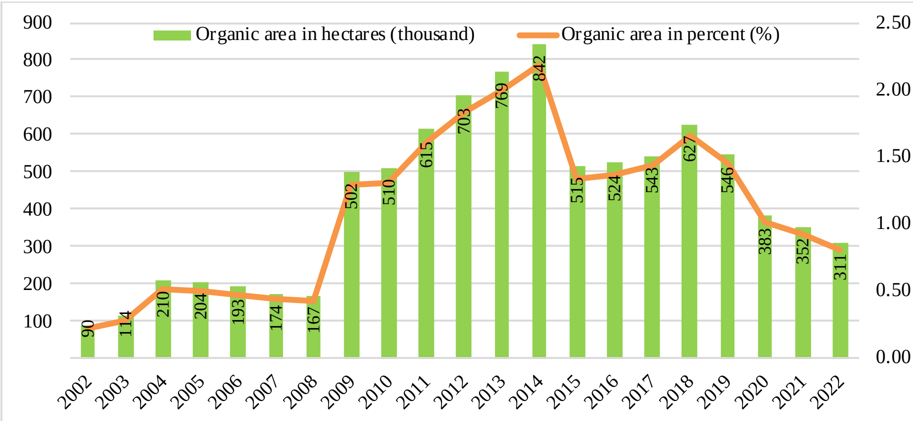

Figure 2. Growth of organic agricultural land and organic share between 2000 and 2021 in Türkiye
Source: TURKSTAT, 2022

ORGANIC AGRICULTURE IN TR83 REGION

TR83 Region is located in the north of Anatolia, in the central part of the Black Sea Region (see Figure 3), between 40° 00' and 41° 45' north latitudes and 34° 00' - 37° 40' east longitudes. The region covers approximately 4.85% of the surface area of Türkiye, with a surface area of approximately 37, 937 km². In TR83 Region, 54.3% is covered with agricultural and other lands, 34.9% with forests and shrubs, and the remaining 10.8% is covered with meadows and pastures (MBA, 2023). TR83 Region includes the provinces of Samsun, Tokat, Çorum and Amasya, with respective populations of 1.3 million, 407 thousand, 395 thousand and 252 thousand people (TURKSTAT, 2022).

Figure 3. TR83 Region, Türkiye

Organic Plant Production in TR83 Region

The growth of the number of organic farmers and planted area in the TR83 region and Türkiye between 2002 and 2022 is given in Table 3. In 2022 and the TR83 region, 28,362 tons of organic production have been performed with 1,416 producers on a 4,572 ha area, which is 4% of the number of organic producers and 2.36% of the organic production area in Türkiye. In 2007, 5.35% of Türkiye's organic farming area was in the TR83 region. The province with the largest organic agricultural planted area in the TR83 region is Samsun province (4,402 hectares, 96%), which constitutes 2.26% of the organic area in Türkiye.

Table 3. Development of the number organic farmers and planted area in TR83 Region and Türkiye

	Amasya		Çorum		Samsun		Tokat		TR83		Türkiye	
	Number of farmers	Planted area (ha)	Number of farmers	Planted area (ha)	Number of farmers	Planted area (ha)	Number of farmers	Planted area (ha)	Number of farmers	Planted area (ha)	Number of farmers	Planted area (ha)
2002	-	-	-	-	4	132	1	1929	5	2061	12428	89826
2003	-	-	-	-	15	109	-	1849	15	1958	13044	103190
2004	-	-	-	-	68	882	2	2250	70	3132	9314	162192
2005	-	-	-	-	65	682	1	3000	66	3682	9427	175073
2006	3	21	-	-	56	1475	11	3032	70	4529	8654	162131
2007	12	9	-	-	51	4505	2	2728	65	7243	10553	135359
2008	13	10	-	-	115	4532	3	2461	131	7005	9384	141752
2009	53	430	4	1	183	2687	236	16971	476	20091	19706	469557
2010	8	32	-	-	160	620	101	267	269	920	11179	63039
2011	6	6	-	-	310	1342	120	288	436	1637	15642	146402
2012	6	29	-	-	353	1359	113	277	472	1666	24406	212345
2013	6	7	-	-	442	1920	115	292	563	2220	26181	242361
2014	8	7	20	8	622	2264	153	362	803	2642	33738	302315
2015	29	62	1	-	676	2087	157	302	863	2451	36732	312621
2016	11	69	23	10	788	2304	277	813	1099	3196	45991	338977
2017	12	75	29	14	923	3164	286	668	1250	3921	51796	355853
2018	9	71	23	80	1013	3343	241	684	1286	4179	54666	365889
2019	8	74	18	14	1099	4200	257	736	1382	5024	53782	348460
2020	8	64	19	16	1159	4414	141	364	1327	4858	40984	233706
2021	7	64	5	6	1385	4378	100	222	1497	4672	38748	216863
2022	7	62	5	7	1352	4402	52	100	1416	4572	36093	193988

Source: TURKSTAT, 2022.

According to the Table 4, organic production in the TR83 region has increased significantly in the last twenty years. In 2007, 10% of Türkiye's organic production took place in the TR83 region, with almost 43 thousand metric tonnes. Whereas organic production in Türkiye was at a maximum level with 1.7 million tons in 2018 and at a minimum level with 278 thousand tons in 2004, organic production in the TR83 region was at a maximum level with almost 43 thousand tons in 2007 and at a minimum level with 242 tons in 2003.

Table 4. Development of organic production in the TR83 Region and Türkiye (tonnes)

	Amasya	Çorum	Samsun	Tokat	TR83	Türkiye
2002	-	-	596	1500	2096	310124
2003	-	-	142	100	242	291875
2004	-	-	1579	720	2299	278725
2005	-	-	1538	65	1603	289082
2006	478	-	1408	97	1983	309521
2007	66	-	42902	51	42960	431202
2008	173	-	4370	108	4651	415380
2009	847	2	2315	782	3947	318164
2010	144	-	2237	621	3003	331361
2011	36	-	2250	5303	7590	639810
2012	222	-	3449	1555	5227	876371
2013	106	-	7145	713	7965	922623
2014	131	73	5650	6074	11930	1065567
2015	626	19	4200	5593	10438	1164202
2016	247	10	4480	17377	22114	1627106
2017	235	98	11403	1703	13439	1610913
2018	408	4453	12538	1881	19281	1714769
2019	295	109	15674	2245	18324	1374535
2020	380	161	22709	1335	24586	1123409
2021	313	32	19597	2121	22066	1101236
2022	124	43	27199	995	28362	1153161

Source: TURKSTAT, 2022.

The place of the TR83 region in Türkiye organic agriculture according to the years with regard to percent is given in Figure 6. The number of farmers planted area and production are displayed on the first axis, with data ranging from 0.04% to 9.96%. The number of crops is given on the second axis, with data ranging from 6.67% to 71.36%. According to the figure, in 2022, approximately 4% of the number of organic farmers, 2.4% of the organic planted area, and 2.5% of the organic production in Türkiye will be in the TR83 region.

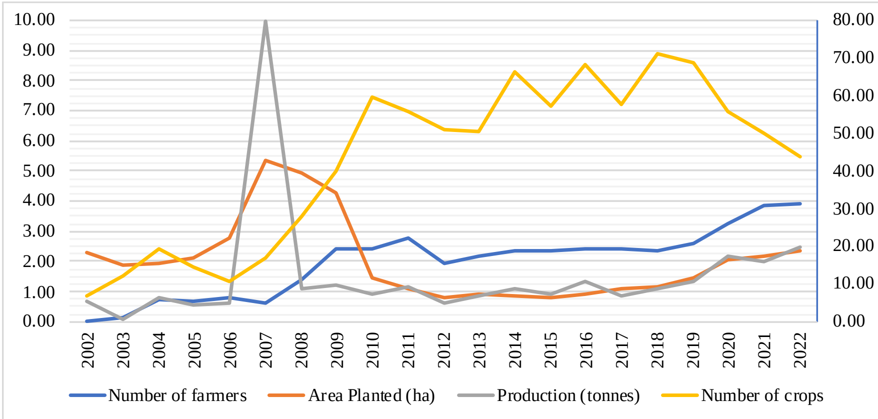

Figure 6. The place of the TR83 region in Türkiye organic agriculture according to the years (%)

Source: TURKSTAT, 2022.

Organic Livestock Production in the TR83 Region

The European Green Deal aims to foster a transition towards organic agriculture and livestock farming as an alternative production system, emphasizing their substantial positive impact on climate change mitigation and adaptation. The vision entails member states shifting approximately 25% of their conventional agricultural production to organic systems by 2030 (Escarus, 2021; Semtrio, 2021). There have been significant developments in organic animal production around the world and in Türkiye. However, the existence of organic animals and the number of enterprises in our country are not yet sufficient. The most important reasons for this are the problems experienced in the supply of organic feed and wandering areas, high costs, and insufficient demand due to the low purchasing power of consumer in the domestic market. When organic animal existence is examined by province in Türkiye; while the largest cattle presence is in Çanakkale with a 35% share (2,786), it is followed by Manisa with a 26% share (2,083) and Niğde with a 15% share (1,165). According to the presence of small cattle, Çanakkale ranks first with 1997 animals, which constitutes 81.4% of the total animal population. While Samsun province, located in the TR83 region, is the most important province of Türkiye in terms of the presence of organic poultry (187,583), Sakarya (155,600) and

Izmir (140,562) provinces also stand out with the presence of organic poultry (MoAF, 2021).

The development of organic meat and milk production in the TR83 region is presented in Table 5. According to the data, Amasya, Çorum and Tokat, located in TR83 Region, did not have organic meat and milk production, except for 2020. Organic meat and milk have been produced in Samsun since 2012. In the province, where approximately 30 tons of organic meat and 2,500 tons of milk were produced in 2021, organic meat and milk production were not realized in 2022.

Table 5. Development of organic meat and milk livestock production in the TR83 region

	Number of farmers				Meat Production (tonnes)				Milk Production (tonnes)			
	Amasya	Çorum	Samsun	Tokat	Amasya	Çorum	Samsun	Tokat	Amasya	Çorum	Samsun	Tokat
2007	-	-	1	-	-	-	-	-	-	-	-	-
2008	-	-	2	-	-	-	7.5	-	-	-	-	-
2009	-	-	1	-	-	-	-	-	-	-	-	-
2010	-	-	1	-	-	-	-	-	-	-	-	-
2011	-	-	1	-	-	-	-	-	-	-	-	-
2012	-	-	3	-	-	-	26	-	-	-	1015	-
2013	-	-	2	-	-	-	25	-	-	-	-	-
2014	-	-	3	-	-	-	-	-	-	-	972	-
2015	-	-	3	-	-	-	44	-	-	-	1590	-
2016	-	-	3	-	-	-	36	-	-	-	2212	-
2017	-	-	2	-	-	-	40	-	-	-	1494	-
2018	-	1	2	-	-	-	40	-	-	-	1973	-
2019	-	-	4	-	-	-	36	-	-	-	1942	-
2020	-	-	3	1	-	-	1.1	4.1	-	-	1836	-
2021	-	-	2	-	-	-	29.28	-	-	-	2587	-
2022	-	-	-	-	-	-	-	-	-	-	-	-

Source: TURKSTAT, 2022.

According to the Middle Black Sea Development Agency report, Çorum and Samsun located, in TR83 Region, are the foremost production centers in Türkiye in egg, poultry, and broiler production and TR83 Region accounts for 8% of overall national egg production. (Anonymous, 2022). The development of organic egg and honey production in TR83 Region is given in Table 6. Organic egg production in the TR83 Region started in 2008 with Samsun Province, organic honey production started in 2009 with Çorum and Tokat. Although organic egg production in Türkiye increased significantly until 2020, it has been on a downward trend for the last two years. And Samsun province plays the most important role because it has the largest production in the country. In other TR83 region provinces, organic egg production is not carried out. When the TR83 region is examined in terms of organic honey production, it is seen that there is no organic honey production in Samsun this time, and other provinces come to the fore, especially Çorum province.

Table 6. Development of organic egg and honey production in the TR83 Region

	Egg Production (piece)						Honey Production (tonnes)			
	Amasya	Çorum	Samsun	Tokat	TR83 (%)	Türkiye	Amasya	Çorum	Samsun	Tokat
2008	-	-	2000000	-	45.2	4424000	-	-	-	-
2009	-	-	3164100	-	26.8	11767400	-	2.5	-	1.5
2010	-	-	6000000	-	33.5	17889808	-	-	-	3
2011	-	-	6800000	-	25.9	26236920	-	3.8	-	5.5
2012	-	-	8100000	-	22.4	36105556	-	3.9	-	-
2013	-	-	9263850	-	19.2	48040778	-	4.12	-	231
2014	-	-	10824000	-	16.6	64898912	-	3	-	-
2015	-	-	14040000	-	23.8	58938769	-	1.74	-	-
2016	-	-	32959500	-	22.3	147600367	-	2	-	-
2017	-	-	27922500	-	17.3	161254080	-	0.6	-	-
2018	-	-	27922500	-	15.9	174675362	3	0.5	-	-
2019	-	2000	30149795	-	16.7	179781501	-	-	-	-
2020	-	-	23411665	-	12.8	182991927	-	0.8	-	-
2021	-	-	26001432	-	20.2	128691517	-	-	-	-
2022	-	-	-	-	-	87444562	-	0.7	-	-

Source: TURKSTAT, 2022.

The development of organic egg production in the TR83 Region and Türkiye is given in Figure 7. According to the figure, organic egg production has not been realized in Amasya, Çorum and Tokat provinces from the past to the present. Samsun province, located in the TR83 region, has had an important share in Türkiye's organic egg production since 2008. Samsun province had almost one- third of Türkiye's organic egg production, especially between 2008 and 2010. However, Türkiye's organic egg production has decreased by 30% in the last two years compared to the previous year and by 50% in total. In 2022, organic eggs were not produced in Samsun province.

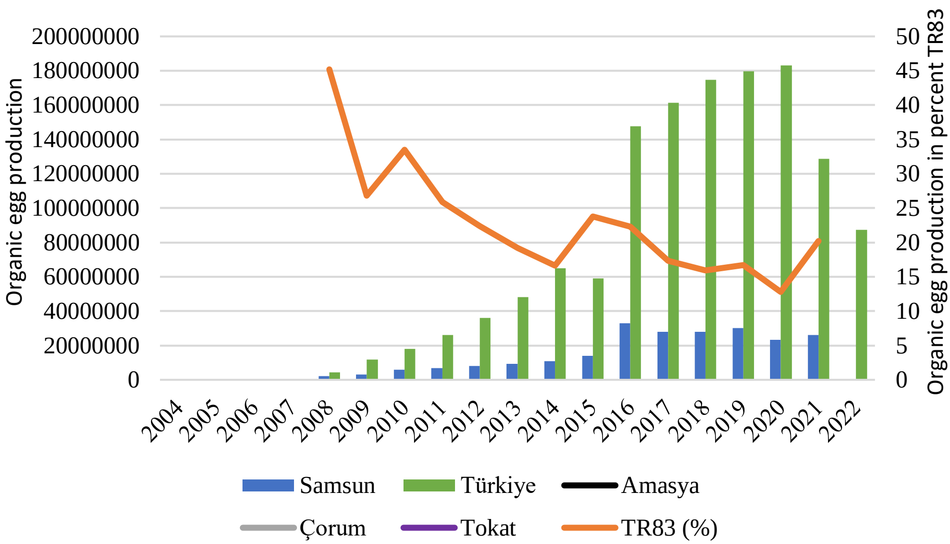

Figure 7: Development of Organic Egg Production in TR83 Region and Share 2004-2022 in Türkiye

CONCLUSION

As of 2021, 3.7 million producers in 191 countries in the world are carrying out organic farming on a 76.4 million ha area. Both organic agricultural land and organic share of total agricultural land, as well as the number of producers, the organic market, and per capita consumption in the world, have continued to increase from the past to the present.

This study evaluates the current status of organic agriculture production in the TR83 region. The findings reveal that the TR83 region holds significant potential in both organic plant and livestock production. In the TR83 region, approximately 1500 producers carry out 29 thousand tons of organic production on a 4572-hectare area. Samsun province, particularly in organic egg production, has consistently represented about half of the country's production in certain years, making it a key contributor to organic production in the TR83 Region. Although organic production, which is in a constant increasing trend worldwide, decreased in Türkiye after 2018, it tends to increase in the TR83 region and Samsun province.

In terms of organic livestock production, it was determined that there has been no organic animal production in Amasya from the past to the present, while Samsun stands out as the province where significant organic animal production took place. Concerning organic meat and milk production in the TR83 Region, it was stated that Amasya, Çorum and Tokat provinces do not engage in organic meat or milk production. Although approximately 30 tons of meat and around 2 thousand tons of organic milk were produced in Samsun province between 2012 and 2021, no organic meat and milk was produced in 2022. In terms of organic honey production, Çorum province stands out in the TR83 region. The TR83 region is a region with high potential in terms of organic plant and livestock production. In order for organic livestock farming to develop in our country, support programs for organic livestock farming should be planned, and to reduce costs, especially the increase in forage plant areas, it should be encouraged. In addition, training and publication activities need to continue increasingly in order to increase the awareness of producers about organic agriculture.

Although organic agriculture is a healthier form of production in terms of human health and provides more environmental benefits compared to conventional agriculture, its yield is lower. For this reason, organic agriculture needs to be more profitable in order to its sustainability.

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CHAPTER IX

RENEWABLE ENERGY AS AN ALTERNATIVE ENERGY SOURCE IN AGRICULTURE

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INTRODUCTION

Sustainable agriculture serves as an alternative solution to ecological challenges associated with food production, as highlighted by Lal (2008). It encompasses natural processes that contribute to the profitability of agricultural enterprises, resource conservation on farms, and the minimization of environmental damage, as emphasized by Chel and Kaushik (2011). In the global context, three pivotal components of development include the environment, economy, and energy (Azad et al., 2015). According to Ibrahiem (2015), energy plays a critical role in human, economic, and societal advancement as well as sustainable development.

Both developed and developing countries heavily rely on fossil energy to fuel growth across various economic sectors such as manufacturing, tourism, transportation, and agriculture (Ben Jebli and Ben Youssef, 2017). The escalation of social and economic activities has resulted in ecological consequences, magnifying the energy problem as a pressing concern for humanity (Nendissa et al., 2022). Dependence solely on non-renewable sources for energy exacerbates environmental issues, even though these resources are considered essential due to their seemingly unlimited availability in the future (Bhatti and Fazal, 2021; Chien et al., 2022; Rehman et al., 2021).

The apprehensions linked to the use of fossil energy can be alleviated by transitioning to renewable energy sources (Martinho, 2018). According to Ben Jebli and Ben Youssef (2017), this change not only addresses environmental issues but also provides advantages for farmers in the social, economic, and environmental domains. The integration of renewable energy sources into agricultural production practices is anticipated to bring about positive environmental changes, fostering improved energy utilization, food security, and the realization of ecological farming goals (Majeed et al., 2023).

MATERIAL AND METHOD

The study relied on secondary data, incorporating various sources such as statistics, reports, pertinent legislation, and prior research publications from relevant institutions and organizations. The results obtained from these sources are given in a tabular format, as required by the extensive literature evaluation that was conducted for this study.

A systematic literature review method was used on the subject. Systematic literature review is accepted as an effective research methodology in examining existing studies and synthesizing the results and findings in a systematic, transparent, and reproducible way (Yıldız, 2022). It is argued that the systematic review process provides a more reliable basis for designing research because it is based on a more comprehensive understanding of what is known about a topic (Bryman, 2016). In the research, three main bibliographic databases, Web of Science, Scopus, and Google Scholar, were examined.

RESEARCH FINDINGS

Energy Demand in Agricultural Production

Agriculture is a sector responsible for the production and transformation of essential animal and plant products required for human nutrition into value-added goods. Energy plays a crucial role in facilitating the production and processing of agricultural products (Bonny, 1993). While the agricultural sector in Türkiye may not be the largest energy consumer, there is a substantial demand for energy in rural areas. This demand is attributed to various processes, including soil cultivation, sowing-planting, weed control, irrigation, fertilization, harvesting, transportation, and drying (Yaldız et al., 1993).

In today's world, agriculture stands out as one of the most critical strategic sectors. Despite the significance of agricultural core activities, the current reliance on fossil energy sources persists (Bayrakçı and Koçar, 2012; Hansen et al., 2001). Global reserves utilized in agricultural production are diminishing rapidly, resulting in high energy costs due to supply and demand imbalances. Furthermore, the use of fossil fuels contributes to substantial carbon dioxide emissions, fostering global warming and environmental pollution (Majeed et al., 2023), thereby negatively impacting areas designated for agricultural activities (Bayrakçı and Koçar, 2012; Omer, 2008).

Energy is integral to agriculture, being employed either directly or indirectly (Mohareb et al., 2017). Direct energy usage encompasses various activities within agricultural core operations, such as electricity consumption, utilization of tools and machinery, and the use of fuels for marketing, drying, and cooling equipment (Moerschner and Gerowitt, 2000; B. Zhou et al., 2023; Z. Zhou et al., 2023). Indirect energy usage involves the energy required to produce chemicals, fertilizers, and pesticides used in agriculture. In contrast to these conventional resources, Türkiye boasts a diverse array of renewable energy sources, including biomass energy, solar energy, geothermal energy, wind energy, and hydropower (Bayrakçı and Koçar, 2012). Leveraging these renewable energy sources in agricultural core activities can yield numerous economic, environmental, and social benefits for farmers, aligning with the concept of "sustainable development" and contributing positively to the country. Renewable energy sources in agricultural production (Bayrakçı and Koçar, 2012):

- Solar energy presents diverse applications in agriculture, serving purposes such as lighting greenhouses, providing heating, and cooling solutions, drying agricultural products, and irrigating fields.
- Modern biofuels, including biogas and bioethanol, along with various agricultural wastes like wheat straw, grain dust, and oat husks, emerge as novel energy sources applicable to the agricultural sector.
- Geothermal energy proves to be a valuable resource with applications spanning soil improvement, aquaculture, heating barns and greenhouses, as well as heating soil in open areas. Additionally, geothermal energy plays a role in the drying of agricultural products, showcasing its versatile contributions to diverse agricultural needs.
- Wind energy stands as a viable option for agriculture, contributing to activities such as generating electrical energy, irrigating fields, and grinding certain crops.
- Hydroelectricity, derived from water sources, assumes a crucial role in agriculture by facilitating electricity generation, supplying drinking water, and supporting irrigation. Furthermore, it promotes equitable water distribution among farmers, contributing to sustainable water management practices in agriculture (Bayrakçı and Koçar, 2012).
- The transition to renewable energy sources in the agricultural sector holds significant implications, impacting various factors, including its

role in mitigating global warming (Okumuş, 2020). This shift reflects a commitment to adopting more sustainable and environmentally conscious practices within the agricultural industry.

Energy plays a central role in food systems. It is consumed not only in primary production but also in secondary operations such as drying, cooling, storage, transport, and distribution (Figure 1).

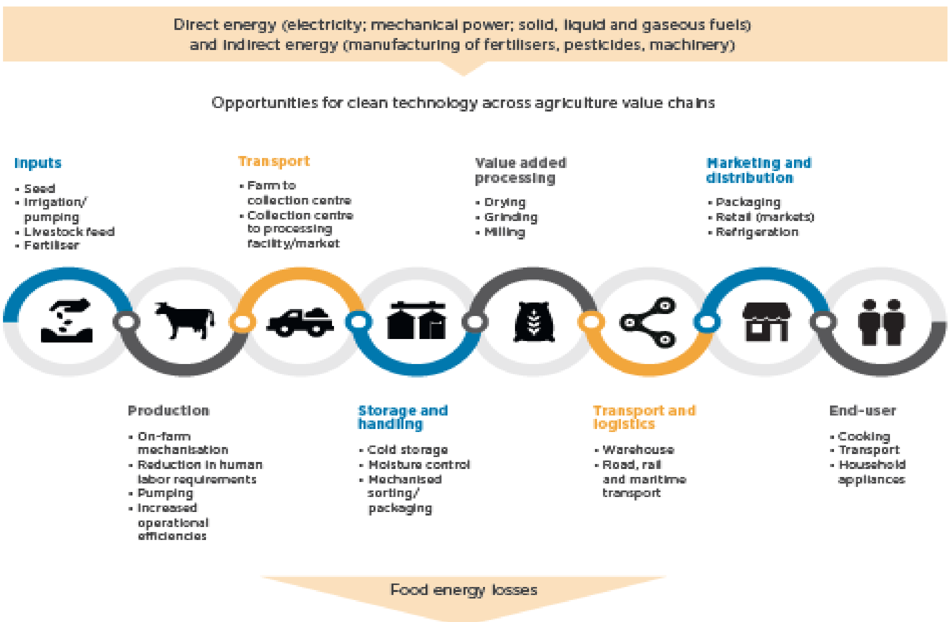

Figure 1. Energy flow in agri-food systems (FAO, 2021)

Figure 2 illustrates the global utilization of renewable energy sources. Notably, in 2021, hydropower emerged as the most widely employed renewable energy source worldwide.

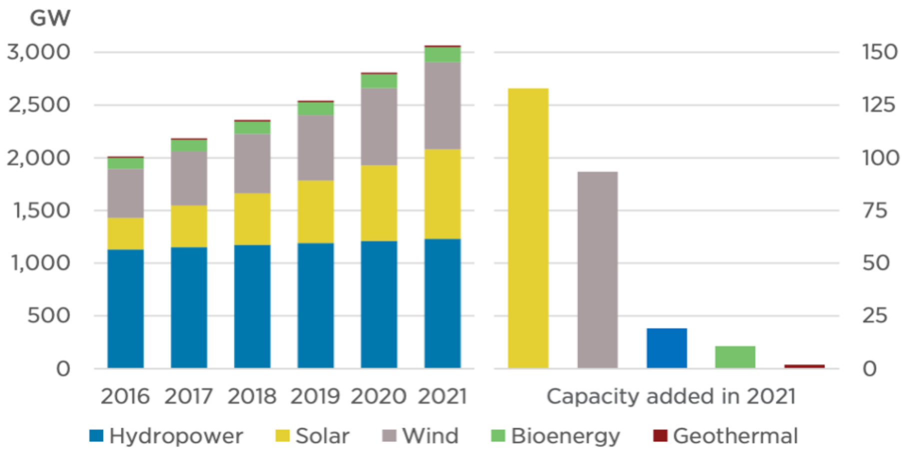

Figure 2. Renewable energy use in the world (FAO, 2021)

The renewable energy sources employed in Türkiye are depicted in Table 1. As per the data presented in the table, hydroelectricity stands out as the most utilized renewable energy source in 2022.

Table 1. Renewable Energy Resources Used in Türkiye (IRENA, 2022)

	2015	2016	2017	2018	2019	2020	2021	2022
Renewable energy	31,787	34,805	39,219	42,817	45,172	50,292	54,759	57,800
Hydroelectric (MW)	25868	26681	27273	28291	28503	30984	31493	31571
Wind	4503	5751	6516	7005	7591	8832	10607	11396
Solar-Solar cell	250	834	3422	5064	5996	6668	7817	9426
Bioenergy	271	359	472	587	784	1097	1583	1858
Solid biofuels and renewable waste	12	55	83	130	216	334	545	696
Liquid biofuel	7	7	12	19	19	23	51	51
Biogas	252	297	377	438	548	741	987	1111
Geothermal	624	821	1064	1283	1515	1613	1676	1691

According to Figure 3, 53.9% of the electrical energy consumed in Türkiye is derived from renewable energy sources (Figure 3).

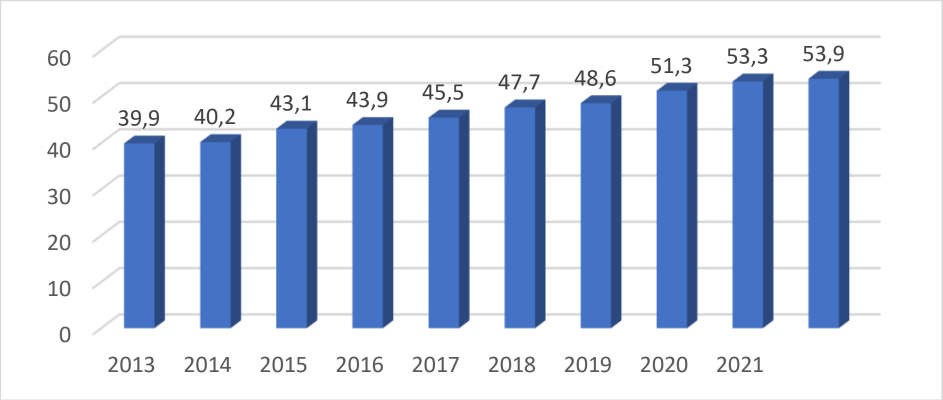

Figure 3. Share of renewable energy in Türkiye's electricity capacity (TETC, 2023)

Renewable Energy Sources in Agricultural Production

Solar Energy

The sun stands as the Earth's most abundant energy source. Naturally occurring solar energy reaches the Earth at a rate of 120 petawatts, signifying that the energy received from the sun in a single day has the potential to meet global energy needs for over 20 years. Solar energy, being the cleanest and most plentiful renewable natural resource, is widely harnessed (Acosta-Silva et al., 2019). This radiant energy originates from the sun's core through fusion, where hydrogen gas transforms into helium (Morse, 1977).

Türkiye, situated in a solar-rich region due to its geographical location, is well-suited for various solar energy applications. The Mediterranean region, ranking second in Türkiye in terms of sunshine duration, contributes significantly to the country's solar energy potential. A breakdown of solar energy potential by region in Türkiye is provided in Table 2 (Selbaş et al., 2003).

Table 2. Solar energy potential by region in Türkiye (Üçgül, 2009)

	Solar Energy	Sunshine Period		
Area	Annual average kWh-m^2.year	Annual average h-year	Most h-month	Least h-ay
Southeastern Anatolia	1491.2	3016	407	126
Mediterranean	1452.7	2923	360	101
Central Anatolia	1432.6	2712	381	98
Aegean	1406.6	2726	371	96
Eastern Anatolia	1398.4	2693	373	165
Marmara	1144.2	2528	351	87
Black Sea	1086.3	1966	273	82

Solar energy stands as a renewable energy source devoid of environmental pollution. Previously deemed uneconomical, recent years have witnessed a significant economic feasibility in specific applications of solar energy, particularly in response to soaring fuel prices. Utilizing solar energy systems emerges as a crucial alternative to conventional energy sources like oil and coal (Gençoğlu, 2005). Solar energy systems, encompassing photoelectricity, solar heat, and solar energy, offer substantial environmental advantages compared to traditional energy sources, contributing to the sustainable development of human activities (Tsoutsos et al., 2005).

The applications of solar energy extend across various sectors, impacting daily life, communications, industry, power plants, agriculture, and even space. Contemporary solar energy applications gaining prominence include converting solar energy into electricity, using solar water pumps for agricultural irrigation, and harnessing solar energy for producing hydrogen—the fuel of the future—from water (Gençoğlu, 2005; Üçgül, 2009).

All renewable energy sources can effectively address the electrical energy needs of the agricultural sector (Taşkın and Vardar, 2016). Solar energy, specifically, plays a pivotal role in modern agricultural practices, enhancing their sustainability and efficiency (Gorjian and Campana, 2022). Solar energy panels find applications in irrigation systems, greenhouse heating, and meeting electricity requirements (Chikaire et al., 2010; Mekhilef et al., 2013). The benefits of solar-powered agricultural practices encompass reduced energy costs, minimized environmental impacts, and increased energy independence (Aroonsrimorakot et al., 2020). Additionally, solar-powered farming practices contribute to farmers achieving energy security, reducing reliance on traditional energy sources, and fostering more sustainable agricultural operations.

Despite these advantages, the widespread adoption of solar farming practices faces challenges, including investment costs, technological infrastructure, and a lack of knowledge that may hinder farmers' transition to this technology. Consequently, public policies and support programs can play a crucial role in promoting and expanding solar agriculture.

Solar energy finds diverse applications in agriculture, as outlined below:

A. Electricity Generation: One prominent use of solar energy involves the deployment of solar panels. These panels convert sunlight into electricity, storing the generated energy with the assistance of batteries. The stored energy proves particularly useful in remote locations or areas without a transmission line. Opting for solar panels in regions where transmitting electrical energy is costly represents a cost-effective and advantageous choice (Değişman and Taşkesen, 2023).

Solar energy can also be directly transformed into electrical energy through semiconductors using photovoltaic (PV) devices (Acosta-Silva et al., 2019; Torshizi and Mighani, 2017). This method facilitates electricity production through panels installed on agricultural lands. Solar PV systems are versatile, providing electricity, heat, or a combination of both (using PV systems). In smaller-scale farms and protected growing environments like greenhouses, distributed PV systems are preferred. Conversely, large, centralized PV power plants are required for farms with extensive usable areas (Bojić and Blagojević, 2006; Caballero et al., 2013; Fernandez-Infantes et al., 2006).

Electricity generation through solar panels stands out as one of the most common applications in agriculture. The electrical energy produced is employed to operate agricultural machinery, support irrigation systems, cool storage areas, and fulfill various other electrical needs.

B. Greenhouse Heating: Solar energy proves beneficial for heating greenhouse systems, particularly in cold climates. The heat derived from solar energy plays a crucial role in regulating the temperature inside the greenhouse, supporting optimal plant growth.

The utilization of solar energy for heating greenhouse systems is widespread. This application is often employed to bolster agricultural activities conducted within greenhouses, such as fruit, vegetable, or flower production.

Greenhouses are designed to allow the necessary sunlight for plant photosynthesis while concurrently maintaining an optimal temperature (Adekoya et al., 2022). Thermal energy obtained from the radiation of solar-heated greenhouses or collectors, along with the transfer of heated fluids, serves to regulate greenhouse temperatures (Figure 4).

Figure 4. An example of a solar greenhouse (Torshizi and Mighani, 2017)

Another greenhouse type involves the utilization of photovoltaic cells to convert solar radiation energy into electricity, subsequently applying it within the greenhouse (Santamouris et al., 1994). This cultivation system represents a greenhouse with controlled indoor temperature and humidity conditions, aiming to enhance efficiency through the utilization of solar energy, as illustrated in Figure 5. The energy, in the form of DC power, is transferred from the solar panel to the battery. This DC power source is then conveyed from the battery to the inverter, converting it into an AC power source. The alternating current is employed to generate heat within the greenhouse or operate fans for temperature regulation (Sharma and Samuel, 2014).

Figure 5: A solar panel energy system is used as an indoor fan to control temperature (Aroonsrimorakot et al., 2020).

C. Irrigation Systems: Solar energy finds application in powering various irrigation systems, including drip irrigation and pivot irrigation methods. The use of solar power in irrigation systems contributes to enhanced water resource efficiency and conservation.

A solar panel system offers green energy at an affordable cost, making it an optimal solution for remote operations such as pumping water for crop irrigation (Eker, 2005). However, the implementation of solar panel technology systems requires certain components, including sufficient sunlight, solar panels, a pump controller, a motor pump, a water source, and a water tank. A solar panel typically comprises multiple silicon cells, or solar cells, with the solar cell being the smallest unit. When sunlight strikes the solar panel, the solar cells absorb the energy, which is then converted into direct current (DC) electricity using semiconductors. Subsequently, an inverter in the pump controller transforms the direct current into alternating or alternating current, and the generated energy powers the motor pump. The motor pump then facilitates the pumping of water from the water source, collecting it in the water tank. This process is illustrated in Figure 6, depicting the utilization of water for irrigation on rural farms (Aroonsrimorakot et al., 2020).

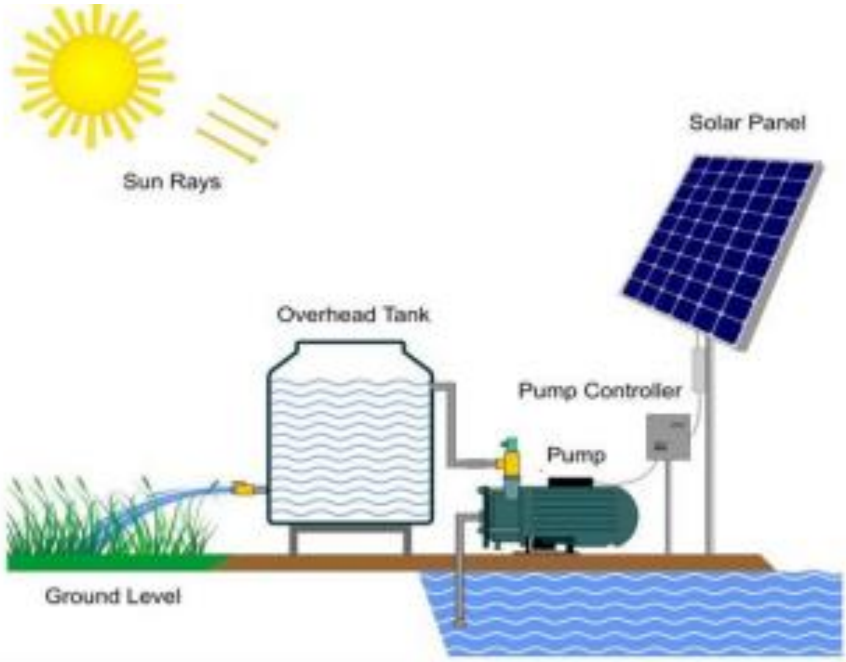

Figure 6: Operation of a solar panel technology system for irrigation (Kodirov et al., 2020)

Solar energy-based irrigation systems emerge as an effective solution for water management, particularly in regions facing limitations in water resources. These systems demonstrate the capability to utilize water more efficiently, thereby contributing to the reduction of irrigation costs, all made possible through the utilization of solar energy.

D. Cooling and Storage: Solar energy proves instrumental in the storage and cooling of agricultural products. Cold storage systems or solar-powered refrigeration systems play a pivotal role in preserving the quality of harvested products.

E. Illumination: Solar energy can be harnessed to provide lighting within greenhouses or across agricultural land. Solar energy-powered lighting systems serve to support plant growth, especially in regions that may not receive sufficient daylight during the winter months.

F. Livestock: Solar energy finds applications in powering animal farms, facilitating water pumping, and heating animal shelters, as illustrated in Figure 7.

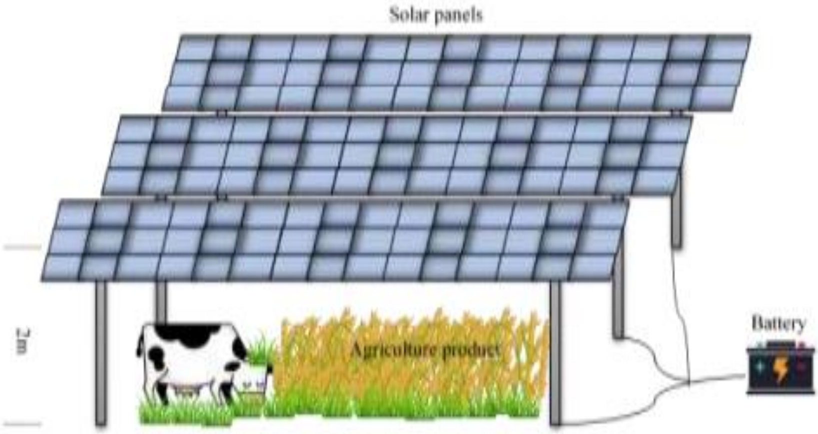

Figure 7: Solar energy systems animal farms (Aroonsrimorakot et al., 2020)

These categories encompass a broad spectrum of solar energy applications within the agricultural sector. Each practice offers farmers a range of benefits, including the reduction of energy costs, minimizing environmental impacts, and enhancing agricultural productivity.

Wind Energy

Wind energy serves as a renewable source utilized for the generation of electrical energy through wind turbines, representing one of the most common and commercially available options within the realm of renewable energy sources (Albostan et al., 2009; Yılmaz, 2012).

The genesis of wind power lies in the unequal heating of the Earth's surface by the Sun and the resulting contrast in temperatures between the surface and the Earth's hot core (Chel and Kaushik, 2011). This temperature differential leads to the formation of low- and high-pressure centers and subsequent air movement, creating varying amounts of kinetic energy in the process (Bıçakçı et al., 2023; Majeed et al., 2023). Extracting direct mechanical power or electrical energy from the wind involves harnessing the kinetic energy through the rotation of propellers.

To generate electrical energy efficiently through turbines, specific geographical conditions related to wind speed, frequency, and direction must be met. While energy production is feasible even in regions with light winds, where the wind speed is as low as 3 m-sec-1 or around 8-10 km--h-1, studies indicate that, for economically viable electricity production, a minimum wind speed of 5-6 m-sec-1, or 18 km-h-1 to -19 km-h-1, is necessary (Figure 8). As wind speed increases, more pressure is exerted on the turbine blades, causing the turbine to rotate faster, and resulting in a higher production of energy (Bıçakçı et al., 2023).

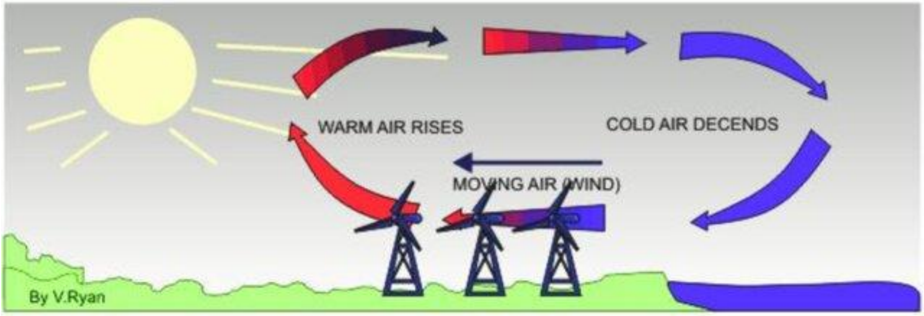

Figure 8: Conversion of wind into wind energy (Afroz, 2011)

Wind turbines can be strategically placed on agricultural lands, allowing for the simultaneous operation of agricultural activities and wind energy production. This dual usage presents an opportunity for farmers to generate additional income. Moreover, wind energy can effectively address the energy needs of agriculture, finding applications in various agricultural processes such as greenhouse air conditioning, electrical applications, irrigation and heat pump applications, drainage applications, windmill facilities, and cooling applications.

Notably, the use of wind energy in agricultural production is often considered more advantageous, particularly when compared to solar panels installed on agricultural lands. The substantial coverage of agricultural production areas by solar panels can limit available space for farming activities, making the utilization of wind energy more favorable (Sheikh, 2010). For instance, a 10-kW wind turbine typically has a mast bottom diameter of 550 mm, and due to their compact design, these turbines have minimal impact on agricultural activities and productivity (Öztürk et al., 2010).

While wind energy holds the potential for sustainable use in agricultural areas, its successful implementation necessitates thorough planning and environmental awareness. This approach ensures that energy production can be increased while simultaneously allowing agricultural activities to continue in a sustainable manner. Wind energy systems employed in agricultural areas generally find utility in the following applications:

A. **Pumping water using a wind turbine:**Wind energy, particularly in the form of wind turbines, is notably employed to operate irrigation systems, facilitating the raising of water for irrigation purposes. In wind energy applications, turbines with multiple blades yield efficient and economical shaft power for water pumping. Figure 9 illustrates the diagram of a water pumping system utilizing wind energy. The extraction of water involves utilizing a pump placed in underground water sources, harnessing the power of the wind for the pumping process (Taşkın and Vardar, 2016).

The cost of irrigation water represents a significant expense in agricultural production, particularly in regions where water is extracted from underground sources through water engines. In such cases, the use of wind power serves as an economical and environmentally friendly alternative to water extraction methods involving diesel fuel or electric motors (Çelik et al., 2017). Wind turbines offer substantial advantages in regions with shorter rainy seasons, where there is an increased demand for pumped water. Once wind turbine water pumps are installed on a farm, they enable the cultivation of higher-value crops throughout the year (Otanicar et al., 2012), while also providing water for animals.

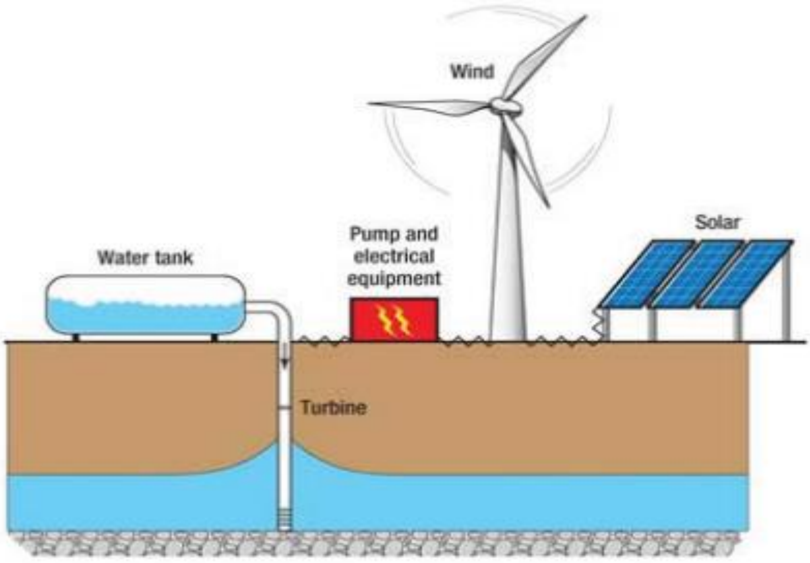

Figure 9: Water pumping plant (Bansod et al., 2019).

Wind turbines power water pumps for irrigation purposes, eliminating the need and cost associated with installing electrical equipment such as power lines, transformers, and poles.

B. **Generating electricity from wind turbines:** Large turbines are employed to generate electrical energy for the grid and are typically installed on or near agricultural land. They can produce substantial amounts of energy. To significantly enhance the yield of agricultural products, the promotion of wind energy should target farms with substantial electricity needs (Chel and Kaushik, 2011). Because wind turbine electricity increases agricultural output, it could improve rural people's standard of living. These wind energy systems serve to support agricultural activities and offer additional income opportunities for farmers. The selection of these systems may vary based on the farmer's needs, land utilization, and regional conditions. Implementation of such systems contributes to increased energy efficiency, additional income for businesses, and overall sustainability.

However, it is crucial to consider the environmental impacts of wind energy facilities and associated land use issues.

When wind energy is put into use in agricultural areas:

- It is crucial to place wind energy facilities appropriately in agricultural areas to ensure minimal disruption to agricultural activities while allowing them to continue. This involves strategic placement that minimizes land use and optimizes coexistence with farming operations.
- Although wind turbines are efficient sources of electricity, Çelik et al., (2017) point out that they may be dangerous to birds and other wildlife. Therefore, it is essential to take appropriate measures to assess and minimize environmental impacts. This may involve implementing technologies or practices that mitigate risks to wildlife and preserve biodiversity.
- Cooperation between agriculture and energy production can be mutually beneficial in meeting energy needs while sustaining agricultural activities. An example of this collaboration is considering options such as grazing animals or growing crops under wind energy facilities. Such cooperative approaches contribute to a harmonious integration of energy production and agriculture, addressing both energy demands and environmental considerations.

For wind energy projects, obtaining the necessary permits is imperative. Additionally, several crucial factors must be taken into consideration, including compliance with both local and national regulations. This entails ensuring that the proposed wind energy initiatives adhere to the legal requirements and standards set forth by relevant authorities at both the local and national levels. By securing the required permits and aligning with regulatory frameworks, wind energy projects can proceed in a manner that is legally sound and in accordance with established guidelines.

Biomass Energy

Biomass is the name given to organic matter containing various plants and their by-products produced through photosynthesis (Armstrong et al., 2014). This substance consists of biological resources such as plants, trees, food waste, etc. Biomass can be used in many areas, such as energy production, biofuel production, and sustainable agriculture. Using biomass in energy production can be a more environmentally friendly alternative to fossil fuels (Ar et al., 2004). The energy obtained from biomass is called bioenergy.

Biomass energy in agriculture involves utilizing agricultural products or organic materials for energy production. This energy source can be obtained through various methods, including biogas, bioethanol, bio methanol, biohydrogen, biodiesel, biomass heating, and electricity production (TÜBA, 2022). The process may entail converting agricultural waste, plants, or animal manure into energy sources. Biomass energy is considered a sustainable energy source that can contribute to the reduction of environmental impacts.

A. Biogas: During the anaerobic fermentation of biomass, a flammable gas, commonly referred to as swamp gas, garbage gas (landfill gas), or sewer gas, is produced under the influence of different types of bacteria operating at various stages. This gas, which is frequently referred to as "biogas," is produced along with fermented waste that includes both liquid and solid phases (Igoni et al., 2008).The raw materials suitable for biogas production are diverse, including small and large animal feces, slaughterhouse wastes, animal wastes generated during the processing of animal products, straw, stubble, corn residues, unprocessed parts of plants (such as finely chopped stalks, leaves, and grass residues), and vegetable wastes. Vegetable wastes arising from product processing encompass sewage and paper industry wastes, food industry wastes, bottom sludge, industrial and domestic wastewater with high dissolved organic matter concentrations as well as urban and industrial wastes with organic content (Kendirli and Çakmak, 2010; Weiland, 2010).

Biogas landfills and agricultural wastes are contemporary bioreactors utilizing various energy crops (especially wastewater treatment sludge) as raw materials. Domestic solid waste typically comprises an organic fraction of 30-50%. Utilizing such waste for biogas production in regulated landfills instead of haphazard disposal can significantly contribute to energy production. Current landfills primarily produce landfill gas (biogas) and wastewater as by-products (Themelis and Ulloa, 2007).

The creation of a sanitary landfill involves layering domestic solid waste on an impermeable base made of clay and a membrane to prevent wastewater mixing with groundwater (Figure 10). Drainage pipes at the bottom of the storage area transport leachate to the wastewater treatment plant, and gas chimneys reaching the surface collect the resulting biogas. The collected biogas is burned in a facility for electricity production. A landfill cross-section is depicted below (Themelis and Ulloa, 2007; Warith et al., 2005).

Figure 10: Example of a biogas energy storage site (TÜBA, 2022)

Biogas finds applications in agricultural fields, including fertilizer processing, electricity generation, heat production, cooling, and lighting. Fertilizer processing involves converting animal manures and other organic wastes in livestock enterprises into biogas. The resulting solid fertilizer is a soil-improving compost containing nitrogen (N), phosphorus (P), and potassium (K) elements, which enhance soil fertility and are rich in organic matter (Abebe, 2017). Utilizing and directing this fertilizer sustainably in agriculture holds significance for both agricultural and environmental values, enhancing soil organic content (Çoban, 2023).

The use of biogas in agriculture addresses energy needs, contributes to waste management, and offers environmental benefits by preventing the release of methane gas into the atmosphere. These practices play a pivotal role in enhancing the sustainability of agricultural businesses.

B. Bioethanol: Bioethanol is typically produced from agricultural raw materials containing sugar, such as cane, sugar beets, molasses, and fruits. Sugars are plant-derived biofuels, notably from crops like corn and sugar cane, and can be directly fermented using yeast to yield ethanol (Mussatto et al., 2010). Bioethanol can be blended with gasoline and used in motor vehicles, including tractors. Moreover, agricultural enterprises can establish bioethanol facilities to utilize bioethanol for energy production.

By-products generated during bioethanol production, such as the remaining corn after the bioethanol production process, can be repurposed for animal feed or other agricultural applications. Additionally, the adoption of bioethanol can lead to reduced energy costs in agricultural enterprises, as using it as a heating or energy source is energy-efficient, has a lower carbon footprint, and aids in reducing greenhouse gas emissions.

C. Biodiesel: Biodiesel, categorized as a biofuel, is commonly used in lieu of or in combination with fossil fuels (TÜBA, 2022). It is primarily derived from soybean oil, vegetable oils, corn oil, sunflower oil, or waste oil, among other sources (Özdemir and Mutlubaş, 2016). Biodiesel finds application as fuel in agricultural vehicles, providing an alternative fuel source for agricultural businesses. Additionally, agricultural enterprises can generate electricity using biodiesel generators, utilize biodiesel for heat production, and repurpose by-products from biodiesel production as animal feed or compost fertilizer. Biodiesel offers diverse applications in agriculture, contributing to waste management and enhancing energy efficiency, thereby reducing overall energy costs.

The use of biomass energy in agricultural areas serves to increase energy efficiency and contribute to waste management, ultimately reducing energy costs by meeting the energy needs of agricultural businesses. In summary, biomass energy in agriculture is employed for heating, often derived from sources like wood, vegetable waste, or energy crops. This can be utilized for heating in greenhouses, barns, and other agricultural facilities. Additionally, the production of bioethanol and biodiesel from agricultural products represents another significant application of biomass energy. Agricultural businesses can utilize or sell these biofuels, which are derived from agricultural goods, to satisfy their own energy demands. Agricultural vehicles and machinery can operate using biomass fuel, particularly derived from energy crops.

Hydroelectric Energy

Hydroelectric energy potential is contingent on the rainfall regime (Bozkurt and Tür, 2015). This form of energy, a clean and sustainable source, involves converting the potential energy of water into electrical energy (Oral et al., 2017). Hydroelectric energy is harnessed from moving dams or river flows (Cengiz, 2020), with the amount obtained depending on factors such as flow rate and water volume (Karagöl and Kavaz, 2017). Variables like climate and rainfall can influence the efficiency of hydroelectric power plants, underscoring the importance of water management and basin planning to optimize power generation.

Many countries globally rely on hydroelectric energy to meet their electricity needs, and hydroelectric power plants are also employed for purposes such as water storage and flood prevention. As a national energy source, hydroelectric energy not only offers environmental benefits but also contributes to energy stability and reduces greenhouse gas emissions (Aslan et al., 2021). While hydroelectric power plants necessitate significant infrastructure investments, they yield long-term returns with low operating costs and extended lifetimes. Furthermore, hydroelectric energy serves as a valuable option for energy storage, providing a significant advantage in situations where electricity demand fluctuates. However, the utilization of this energy source requires meticulous planning and sustainable practices.

A. **Water pumping:** Hydroelectric energy can be used to power water pumping systems. This is employed to supply water to irrigation systems. Due to the utilization of hydroelectric energy, extensive agricultural expanses can be efficiently irrigated, particularly in arid regions. Particularly in dry regions, hydroelectric power is used to pump water from highland areas to lowland areas for irrigation canals and drip irrigation systems.

Hydroelectric power also involves the management of water. Sustainable use of water resources for agriculture requires effective control over the water reservoirs of hydroelectric power plants. This ensures efficient use of water and stability in water supply to farmers.

B. **Farm machinery:** Hydroelectric energy can be used as a power source to run tractors, combines and other agricultural machinery. This increases the efficiency of farming operations and provides cost savings to farmers.

C. **Cooling and storage:** Hydroelectric energy can be used for cooling and storing agricultural products. Especially in fruit and vegetable warehouses, cooling systems can be operated with hydroelectric energy, thus ensuring that the products remain fresh.

D. **Farm processing and processed product production:** Hydroelectric energy can be used to meet the energy needs of grain mills, flour mills, dairy processing plants, and other agricultural processing facilities. This makes it easier to process agricultural products and produce more value-added products.

E. Renewable heat production:

Hydroelectric energy can be used for greenhouse heating systems. This can accelerate the growth of plants in greenhouses and support off-season production.

These uses of hydroelectric energy can meet the energy needs of the agricultural sector, promoting sustainable agricultural practices while also reducing energy costs. This supports environmental sustainability while increasing the efficiency of agriculture.

Geothermal Energy

Geothermal energy is a form of renewable energy derived from underground heat sources. Hot water and steam beneath the Earth's crust constitute the origins of geothermal energy (Dipippo, 2015; Erkul, 2012). The geothermal heat stored below the surface is utilized in geothermal power plants for electricity production and heating systems (Eslami-Nejad et al., 2014). Recognized as an environmentally friendly and renewable energy source (DiPippo, 2012; Milora and Tester, 1976), geothermal energy plays a pivotal role in mitigating greenhouse gas emissions. Furthermore, this energy source is considered viable for meeting sustainable and localized energy needs.

Geothermal energy resources offer diverse applications within the agricultural sector.

A. **Soil heating:** Geothermal energy can be utilized in soil heating systems to control soil temperature, prevent freezing, and facilitate off-season crop cultivation. This method is commonly employed in early spring and late autumn to enhance production efficiency. Crucial factors include the depth and spacing of heating pipes, soil temperature, pipe material, and the impact of soil temperature on plant growth (Öztürk, 2005).

B. **Drying procedures:** The drying, storing, and preservation of agricultural products can also benefit from geothermal energy. Hot air sources are employed for crop drying, with vegetables, fruits, grains, and other agricultural items representing the majority of energy-related agricultural consumption. Geothermal energy proves advantageous as it allows the regulation of drying temperatures, replacing traditional methods. The temperature of geothermal water and its alignment with the required plant drying temperature are significant considerations (Lund and Freeston, 2001).

C. **Fish farming:** Geothermal waters find application in controlling water temperature in fish farming facilities, where aquaculture operating temperatures range from 22 ◦C to 30 ◦C depending on the fish species (Günerhan, 2010). Effective temperature control is vital for the healthy growth of fish.

D. **Hot water supply:** In agriculture, geothermal resources can supply hot water for irrigation, preventing plant root freezing by elevating the temperature of irrigation water in cold climates or during chilly seasons, thereby enhancing harvest efficiency.

E. **Greenhouse cultivation:** Moreover, geothermal energy is extensively employed in greenhouse heating systems, enabling temperature adjustments within the greenhouse from 20 °C to 150 °C (Kendirli and Çakmak, 2010). Greenhouse farming necessitates maintaining stable temperature conditions for optimal plant growth, and geothermal heating offers the means to achieve this, allowing growers to engage in off-season production.

In conclusion, geothermal energy presents an environmentally friendly option to meet the energy requirements of agriculture, promoting increased crop productivity. However, successful implementation of these applications relies on the identification of suitable geothermal resources, making geographical factors crucial. Harnessing geothermal energy holds the potential to enhance the sustainability of agriculture and reduce energy costs.

CONCLUSION AND RECOMMENDATIONS

Agricultural production involves both direct and indirect energy consumption, primarily reliant on fossil fuels. However, these fossil fuels are depleting rapidly, leading to increased environmental damage. Urgent measures are imperative to address this issue, and the Green Deal represents a crucial step in this direction. Despite the envisioned transformation in the agricultural sector through the Green Deal, progress remains insufficient. Türkiye's Medium-Term Program incorporates adaptation and transitions to the green economy within the framework of the Green Deal (Anonymous, 2021). A key objective of the Green Deal is the provision of clean and safe energy. In developed countries, the concept of renewable energy sources in agriculture aims to strike a balance between minimizing fossil fuel consumption and mitigating environmental impacts associated with their use, all while maximizing agricultural production (Bolyssov et al., 2019). Renewable energy sources, including solar, wind, biomass, hydroelectric, and geothermal energy, find application in agricultural production. Notably, the livestock sector holds significant potential for biogas generation. It is essential to support farmers in adopting renewable energy resources for agricultural production, with the primary obstacle being the initial investment costs hindering widespread use of renewable energy facilities. Strengthening policy support is crucial to overcoming this barrier.

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CHAPTER X

SUSTAINABLE ANIMAL WASTE MANAGEMENT AND THE POTENTIAL OF BIOGAS IN THE CIRCULAR BIOECONOMY

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INTRODUCTION

In 2050, the world population is expected to increase by more than 50%. The increase in population brings about a 70% rise in food needs and a 100% increase in energy requirements (Clark, 2019). Owing to the rapid population growth and the swift consumption of non-renewable energy sources, there has been an increase in energy demand (Khalil et al., 2019). This situation has revealed the search for alternative sustainable energy sources in developed and developing countries (Khalil et al., 2019; Attard et al., 2020).

Fossil fuels constitute more than two-thirds of the global energy resources used by countries (IEA, 2017). The decline in fossil fuel resources and an increasing amount of waste reveal economic, social, and environmental problems (Abdeshahian et al., 2010; Hosseini et al., 2013; Abdeshahian et al., 2016). Specifically, developing economies can utilize renewable energy sources to decrease greenhouse gas emissions and enhance economic, social, and environmental well-being (Silva-González et al., 2020). Among renewable energy sources, biomass is a renewable energy source that will replace crude oil-based petro-refineries (IEA, 2017).

Biomass is a carbon-neutral, readily available, and renewable feedstock to produce fuels and chemicals (Bridgwater, 2006; IEA, 2017). Agriculture and forestry residues are some of the major renewable energy sources available (Bridgwater, 2006). Globally, 9% of the primary energy supply comes from renewable energy sources (IEA, 2017). These resources are rich in lignocellulosic and agro-industrial wastes, as well as traditional raw materials such as animal manure and sewage sludge found in rural and urban areas (Silva-González et al., 2020). In the last decade, there has been an increase in biofuels such as biodiesel, bioethanol, and biogas. Biofuels are generally obtained from first-generation raw materials (such as oilseeds, corn, sugarcane juice, and molasses). However, due to the food priority of the 1st generation of raw materials, the 2nd generation of raw materials has come to the fore. 2nd-generation raw materials are lignocellulosic raw materials obtained from agricultural residues (Kapoor et al., 2020).

Integrated waste management and biogas production are well-suited for the circular economy. It can contribute to rural development, especially in developing countries (Silva-González et al., 2020). A circular economy is needed in national economies to enhance resource efficiency. To achieve a circular economy, it is necessary to transition away from an economic system reliant on fossil fuels and move towards a bioeconomy (Clark, 2019). Therefore, this study examines the importance of the biogas and animal waste methods in a cyclical bioeconomy.

MATERIAL AND METHOD

This study utilized secondary data, including sector reports, reports prepared by institutions and organizations, as well as national and international articles. To fulfill the study's purpose, animal husbandry data from the Turkish Statistical Institute (TSI) for the year 2020 was utilized to determine the importance of biogas in the circular economy and evaluate animal waste (TSI, 2023). Furthermore, the biogas production potential was determined by calculating the amount of wet waste collected from animal waste in Turkey based on TSI data.

When calculating the amount of wet manure per animal, the percentage (%) of the live animal weight (kg) is considered based on the animal type. The production potential of wet manure in animals may vary depending on the animal's weight, breed, age, sex, feeding type, and climatic conditions of the region (Tırınk, 2022). In this study, considering the literature, it was assumed that the amount of wet manure production would be 20 kg/day for cattle, 2 kg/day for small cattle, and 0.1 kg/day for poultry (Kaygusuz, 2002; Avcioğlu & Turker, 2012). If the animals are kept indoors only at night, 50% of the total waste amount is considered generated waste (Avcioğlu & Turker, 2012). Usable wet manure is calculated based on the number of animals in the barn. According to this calculation, 65% of wet manure in dairy cattle, 25% in beef cattle, 99% in poultry, and 13% in small cattle is considered usable wet manure (Babacan, 2006; Acaroğlu & Aydoğan, 2012). In the literature, two different biogas coefficient assumptions are used depending on the animal type, considering whether the manure is dry or wet (Altikat & Çelik, 2012; Kaya & Öztürk, 2012; Çağlayan & Koçer, 2014; Ilgar, 2016; Baran et al., 2017; Doruk

& Bozdeveci; 2017; Şenol et al., 2017; Bayrak Işık & Polat, 2018; Bulut & Canbaz, 2019; Görgülü, 2019; Kocabey, 2019; Salihoğlu et al., 2019, Yagli & Yıldız, 2019; Yetiş et al., 2019).

Consequently, when determining the dry content of wet manure, the following factors are taken into account: 5-25% for bovine animals, 30% for ovine animals, and 10–90% for poultry (Altikat & Çelik, 2012; Kaya & Öztürk, 2012; Çağlayan & Koçer, 2014; Ilgar, 2016; Baran et al., 2017; Doruk & Bozdeveci, 2017; Şenol et al., 2017; Bayrak Işık & Polat, 2018; Bulut & Canbaz, 2019; Görgülü, 2019; Kocabey, 2019; Yetiş et al., 2019). If biogas consists of 55-70% CH_4, 30-45% CO_2, and 1-3% other gases, the energy content is determined as 6 – 6.5 kWh/m^3 (Deublein & Steinhauser, 2011). It is accepted that the energy content of biogas is 6.5, and the energy conversion efficiency is 40% (Atelge, 2021).

RESEARCH FINDINGS

Circular Bioeconomy and Waste Management

The bioeconomy has gained popularity worldwide in recent years, encompassing all sectors. Generally, it is the science of economics based on biological resources and the functions derived from these resources (European Commission, 2012). The bioeconomy presents an opportunity to substitute fossil, non-renewable, and non-biodegradable materials with renewable and biodegradable alternatives. Additionally, it can offer bio-based materials with novel functionalities that recycling alone cannot achieve, such as increased longevity, enhanced durability, and reduced or no toxicity. The integration of the concepts of circular economy and bioeconomy is sensible and generates synergy (Antikainen et al., 2017). However, these concepts, on their own, do not inherently guarantee sustainability. To produce bio-based products that are sustainable, theytmust not impede food production or have adverse effects on the ecosystem (biodiversity, climate change, etc.). Simultaneously, it should contribute to diminishing reliance on fossil-based and non-renewable energies within the circular economy. This implies that considerations of reusability and recycling needs must be integrated at the design stage when planning new bioproducts (Hetemäki et al., 2017).

Since 2015, the adoption of bioeconomy as a central strategy in overarching sustainability policies has become increasingly prevalent (Duque-Acevedo et al., 2020). However, its definition and approach vary considerably, as this model is referred to as the "sustainable and circular bioeconomy," the "biological transformation of the economy," and the "circular bioeconomy" in different countries (Kothari et al., 2010; Heimann, 2019).

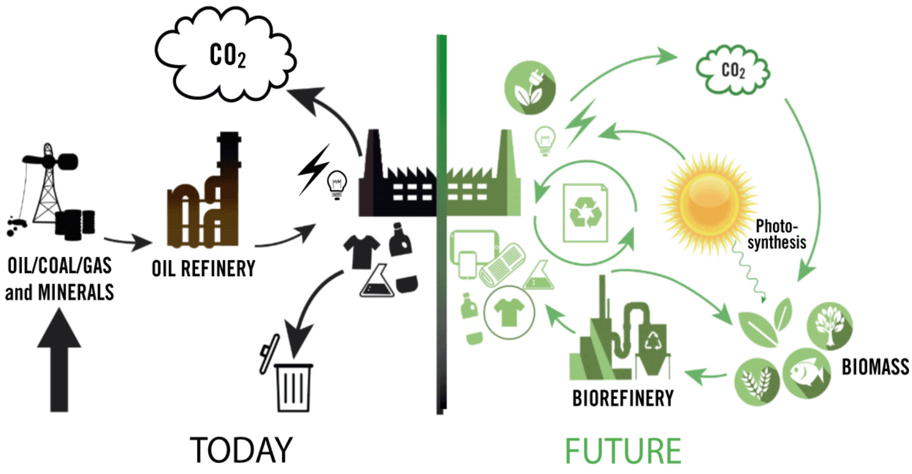

Figure 1: Linear economy and circular economy (Anonymous 2022a)

In the current economy, the process operates linearly, meaning it transforms raw materials into value-added products that are later disposed of as waste. In a circular economy, this process is reversed. The circular economy adheres to several principles, with the first being the elimination of waste and the pollution resulting from it. The second principle involves the circulation of resources, and the third focuses on protecting and renewing nature. This definition serves as a solution to challenges like climate change, biodiversity loss, waste management, and environmental pollution (Anonymous, 2022a; Figure1).

The circular economy aims to establish perfect cycles of products, hasten the shift from consumer to user, and disconnect resource use and environmental impact from economic growth (Lazarevic and Valve, 2017). Represented as a butterfly diagram, the circular economy diagram illustrates material flow and its various stages. The diagram consists of two main loops: the technical cycle and the biological cycle. The technical cycle involves processes such as reuse, repair, reprocessing, and recycling, while the biological cycle focuses on recycling nutrients from biodegradable materials to replenish nature (Anonymous, 2022a).

In the circular economy approach, reducing resource consumption and the use of primary raw materials are crucial. Therefore, it becomes essential to conserve water and energy during the production of a product and increase the utilization of recycled materials in production. Additionally, necessary measures should be taken to minimize the waste generated throughout all processes, from the production of the product to post-consumption (Misir & Arıkan, 2022).

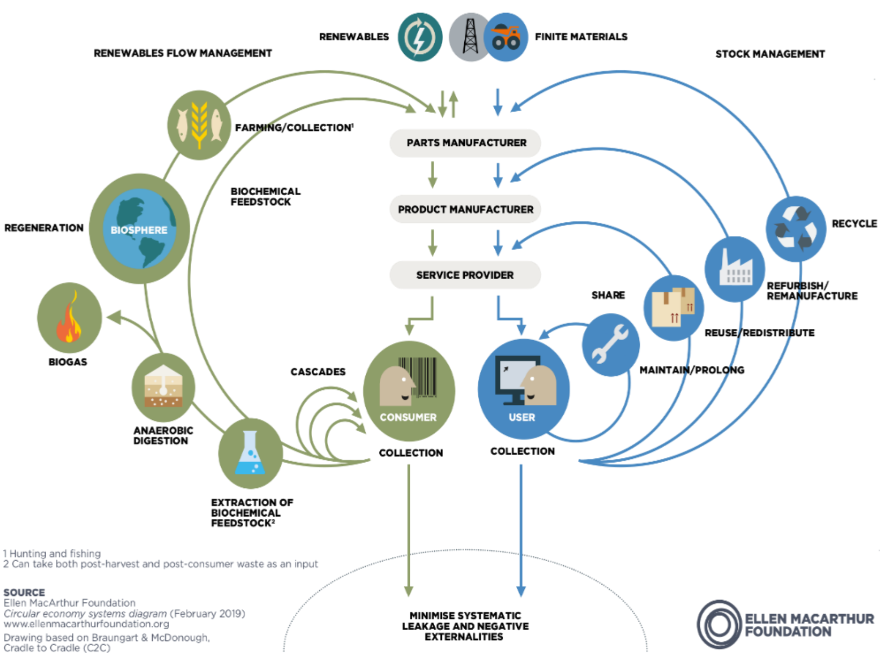

Figure 2: Circular economy, butterfly diagram (Anonymous 2022a)

The circular economy serves as a preventative measure against waste and pollution, recognizing that relying solely on the recycling process may not be sufficient to manage the waste generated by our products (Anonymous, 2022a; Figure 2). In this context, the adoption of zero waste management becomes imperative as an approach to align with and transition into the circular economy concept (Mısır & Arıkan, 2022). The effective utilization of agricultural waste is a key aspect that integrates the agricultural sector into the circular economy (Awasthi et al., 2022).

The surge in world population, economic development, and improved living standards has accelerated the consumption of natural resources, necessitating effective waste management strategies (Minghua et al., 2009; Guerrero et al., 2013). Waste, viewed as a sustainable source of added value, particularly agricultural waste, holds significant value due to its composition of cellulose, hemicellulose, and lignin within the lignocellulosic biomass (Awasthi et al., 2020; Wainaina et al., 2019). Globally, managing agricultural waste poses a challenge for all countries, particularly those in the developing world, leading to environmental pollution and unsustainable economies when left unaddressed (Sharholy et al., 2007; Gentil et al., 2011; Seng et al., 2011; Wilts et al., 2013; Zorpas & Lasaridi 2013; Cecere et al., 2014; Song et al., 2015; Liu et al., 2017). Inability to manage waste results in the depletion of natural resources, environmental pollution, and unsustainable economies. The circular economy emerges as a vital solution to protect natural resources, prevent environmental pollution, and ensure sustainable waste management (Liu et al., 2017). The waste management hierarchy serves as a crucial guide for the circular economy system, ensuring waste prevention is prioritized (Mısır & Arıkan, 2022). A visual representation of the waste management hierarchy is provided in Figure 3 (Zero Waste, 2023).

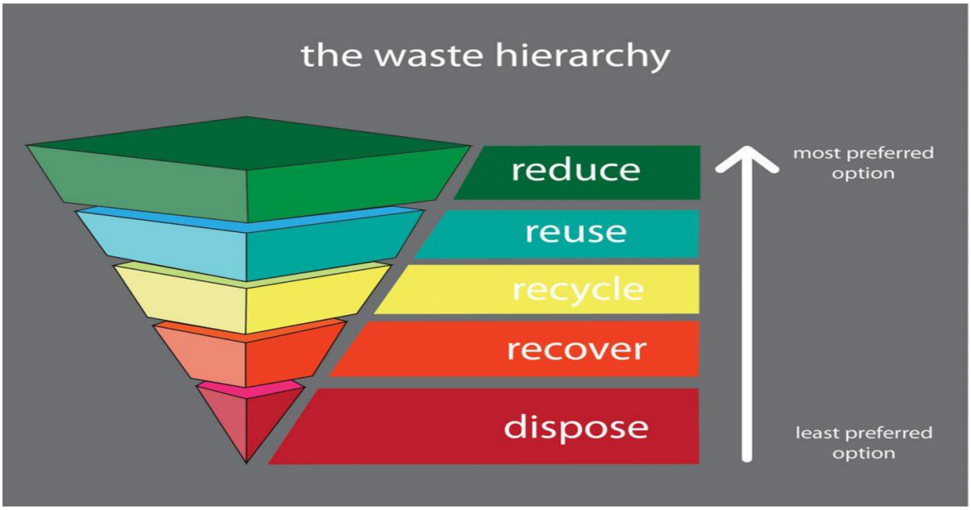

Figure 3: Waste management hierarchy (Zero Waste, 2023).

The Need for a Circular Bioeconomy from Animal Waste

"While the livestock sector experiences rapid growth, the issue of agricultural waste is concurrently on the rise (Xu et al., 2018). In developing countries, there is a lack of effective utilization of animal waste (Siddiki et al., 2021), which represents a potential renewable energy source in these regions. Correct management of animal waste has the potential to eliminate economic, social, and environmental challenges associated with it, ensuring sustainable livestock farming. Trends in resource consumption reduction on Earth's surface and solutions for environmental protection involve minimizing waste released into the environment through enhanced recycling systems and the integration and efficient utilization of abundant renewable energy sources (Drews et al., 2016; Rashid et al., 2019).

The current energy needs of economies are predominantly met by depleting fossil fuels (Toor et al., 2020), and most global economies have followed a linear model since the onset of the Industrial Revolution, relying on purchase, manufacturing, and disposal (Maina & Kachrimanidou, 2017). This linear approach results in continuous resource extraction for production and consumption, lacking a proper framework for recovery and economic revitalization. Recent efforts, however, aim to shift from ecologically unsustainable practices to an environmentally friendly and resource-conserving culture (Rhozyel & Žalpytė, 2018). Concepts of bioeconomy have emerged to utilize diverse biomass types for economic, social, and environmental growth (Khoshnevisan et al., 2021; Reshmy et al., 2022).

Animal Waste Potential for Biogas Production

Significant quantities of agricultural waste biomass are produced and utilized globally (Sommer et al., 2015). This category of waste encompasses residues from animal production, crop cultivation, rural activities, and aquaculture (Ongley et al., 2010). Wastes from both animal and plant sources represent a crucial biomass feedstock due to their potential benefits (Jayasinghe & Hawboldt, 2012). Biomass, derived from biological materials, stands as a renewable natural resource (Noorollahi et al., 2015). Biomass sources comprise long-chain organic substances that are converted into simpler molecules during processing (Hrubant et al., 1978). Organic agricultural waste emerges as a potential energy source. For instance, utilizing manure for biogas production is considered a cost-effective technology to mitigate greenhouse gas (GHG) emissions in agriculture (Sommer et al., 2015). Circular agricultural production is widely adopted in animal husbandry (Li et al., 2016). Implementing necessary changes in livestock practices within a circular economy serves as a precaution against negative environmental impacts and should be regarded as a concept for enhancing resource and energy efficiency (Galka, 2004; Choi et al., 2018).

Agricultural waste remains an underutilized raw material that, with appropriate technologies, could significantly contribute to the decarbonization of the Earth, whether through biofuels or biochemical products. Wastes, particularly agricultural and industrial wastes, possess substantial energy potential anda re capable of providing electricity to approximately 1.8 million homes. The purification of wastewater for use in food and feed production reduces the environmental impact of waste, thereby strengthening the circular bioeconomy (Awasthi et al., 2022).

Table 1. Number of animals in Turkey (TSI, 2023).

Animal Type	**Number of Animals (number)**
Cattle	18,008,377
Small ruminants	57,519,204
Poultry	6,721,263

Turkey's total cattle assets are 18,008,377 heads, small ruminant assets are 57,519,204 heads, and poultry assets are 6,721,263 heads (Table, 1). The assumptions utilized for Turkey's biogas potential are detailed in Table 2. According to the table, the quantity of manure per animal is considered to be 20 kg/day for cattle, 2 kg/ day for sheep, and 0.1 kg/dayfor poultry.

Table 2. Biogas potential assumptions

Acceptance Parameters	Cattle	Sheep and Goats	Poultry
Livestock weight (kg)	135- 800	30- 75	1.5- 12
Wet fertilizer formation (%)	5- 6	4- 5	3- 4
Wet fertilizer production amount (kg day^{-1})	10-20	2	0.08- 0.1
Dry matter content (%)	5- 25	30- 36	10- 90
Volatile dry matter (%)	75- 85	20- 81	60- 80
Availability (%)	25- 65	13	99
Biogas equivalent (m^3 (ton*UKM^{-1})	200- 350	100- 310	310- 650

Turkey's biogas potential is calculated AT 8,126 million m^3 per year Turkey’s total biogas potential has been calculatedat 2.178 million m^3 $year^{-1}$ for 2009 (Avcıoğlu & Türker, 2012).

Table 3. Turkey's biogas (m^3 $year^{-1}$) and electrical energy (kWh) potential

Animal type	Animal type fertilizer amount per animal (kg day^{-1})	Usable fertilizer amount per animal (kg day^{-1})	Dry matter amount per animal (kg day^{-1})	Amount of fertilizer to be used in biogas (tone $year^{-1}$)	Biogas potential (m^3 $year^{-1}$)	Electrical energy potential (kwh)
Cattle	20.00	13.00	3.25	21,362,437.22	7,476,853,025.69	19,439,817,866.79
Sheep and Goats	2.00	0.26	0.08	1,637,571.74	507,647,238.74	1,319,882,820.73
Poultry	0.10	0.10	0.09	218,585.55	142,080,610.53	369,409,587.37
Total					8,126,580,874.96	21,129,110,274.88

Considering the electrical energy potential to be derived from Turkey's biogas resources, a total of 21.1 billion kWh has been determined (Table 3). Turkey's electrical energy consumption reached 332.9 billion kWh in 2021, reflecting an 8.74% increase compared to the previous year (Anonymous, 2022b). The biogas generated from cattle, sheep, and poultry could cover 6.34% of Turkey's total electricity consumption. With a population of 84,680,273 people (TSI, 2023), the per-person electricity consumption in Turkey stands at 3,931 kWh. Therefore, Turkey's biogas potential could meet the annual electrical energy needs of 5,375,000 people.

CONCLUSION AND RECOMMENDATIONS

Due to the rapid population increase in Turkey, two prominent issues emerge: the need for sustainable energy and ensuring safety in waste management. The conversion of animal waste into clean alternative energy, such as biogas, becomes crucial. This study demonstrates the feasibility of producing biogas from organic waste derived from livestock farms, advocating for Turkey to support the implementation of biogas production from animal waste as a vital component of future sustainable energy sources. The biogas potential from animal waste plays a pivotal role in fostering sustainable bioeconomic growth, especially in developing countries. The circular economy, when integrated, can enhance the efficiency and restorative nature of the bioeconomy. Through the establishment of a circular bioeconomy, renewable resources will be utilized, ensuring sustainability. The concepts of bioeconomy and circular economy mutually reinforce each other, suggesting that these concepts, traditionally developed in parallel, should be strategically advanced together. Action plans should be devised to bolster cyclical bioeconomy markets and competitiveness while balancing economic, social, and environmental objectives. This approach supports the development of competitive, innovative, and sustainable supply chain logistics necessary for utilizing renewable energy resources.

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CHAPTER XI

COTTON PRODUCTION AND SUSTAINABILITY IN TÜRKİYE

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INTRODUCTION

Fiber plants have had an important place in human life since ancient times, due to the need for clothing in society (Çopur, 2018). The history of cotton, which is the most produced and used fiber plant in the world dates back to before Christ. Cotton fabrics were first used to wrap mummies in Egypt around 12000 BC (Agriculture in the Classroom, 2021). Another study states that cotton was used in Mexico around 7200-5800 B.C. (Ministry of National Education, 2016). Cotton cultivation is known to have started in Mexico, India, and Pakistan around 5000 BC (Niranjan et al., 2017). It is known that the first cotton on the American continent was used by people living on the coast of Peru. It is estimated that cotton textiles became widespread from here towards the west and north (Çopur, 2018).

In the 1st century BC, cotton was introduced to Anatolia from the Indian subcontinent, leading to the beginning of cotton cultivation in Anatolia (Basal et al., 2019). Cotton gained global recognition as an agricultural product in the 1500s (AITC, 2021). With the industrial revolution, cotton gained an important place in world markets and trade (Damlıbağ, 2011). Today, cotton is one of the most economically important agricultural products in the world (Wang et al., 2012), and it is important for economies as it is an agricultural product produced in many parts of the world (Jans et al., 2021).

Cotton is the natural textile fiber of global importance (Rojo-Gutiérrez et al., 2020) and the most used in the world (Özüdoğru, 2021). This plant has various uses for humans. It is an economically important product for countries with the employment and added value it provides (Gençer et al., 2005; Şahinli, 2011; Uğurlu, 2020; National Cotton Council, 2020). It is also known as "white gold" because it provides foreign currency to some countries (Khan et al., 2020). It is one of the most important raw material sources, especially in the food and textile industries (Küçük and Issı, 2019). Cotton fiber has an economic impact of approximately 600 billion dollars in the world every year (Khan et al., 2020).

Türkiye is one of the most important countries in terms of cotton production. Türkiye, which ranks 7th in world seed cotton production, ranks

2nd in average yield. In Türkiye, cotton is produced intensively in the Southeastern Anatolia, Mediterranean, and Aegean regions. The provinces with the highest cotton production are Şanlıurfa (1.1 million tons), Diyarbakır (408 thousand tons), Aydın (283 thousand tons), Hatay (239 thousand tons), İzmir (172 thousand tons), and Adana (144 thousand tons). (Turkish Statistical Institute, 2022). Almost all (85.5%) of the cotton produced in Türkiye is produced in these 6 provinces.

Recent environmental, social, and economic problems have brought the concept of sustainability to the fore. Cotton is one of the agricultural products subject to sustainability. Cotton production is an agricultural product that causes intense chemical use and excessive water consumption. 11% of the pesticides used in agricultural production in the world are used in cotton production (World Wide Fund for Nature, 2023a).

Widespread use of chemical pesticides in cotton production causes a decrease in the effectiveness of pesticides, an increase in production costs, and various health and environmental problems (Delate et al., 2020). When examined in this respect, studies on the sustainability of cotton production are important.

RESEARCH FINDINGS

Current Status of World Cotton Production

People produce cotton as its seeds are a source of fiber and oil (Niranjan et al., 2017). 90% of the world cotton production is in the northern hemisphere (Basal and Sezener, 2012; Çopur, 2018). 63% of cotton cultivation areas are located in Asia, 20% in America, and 14% in Africa (Agricultural Economic and Policy Development Institute, 2021). Approximately 25 million tons of fiber cotton are produced in the world every year (Khan et al., 2020). The leading countries in cotton production are China, India, the USA, and Brazil, and these countries are expected to increase their production in the next few years. China and India, which have the largest populations in the world, are also leading in cotton production (Kaya, 2017). Cotton production in China has increased rapidly since 1949 (Dai and Dong, 2014). In 2021, 17.3 million tons of seed cotton were produced in China and 17.2 million tons in India. In India, cotton is an important source of income for farmers and offers employment opportunities to the Indian people thanks to the many textile factories in the country (Niranjan et al., 2017).

The largest cotton-producing country after China and India is the United States of America (USA). In 2021, the USA produced 15.5% of the world's cotton, with a production of 11.2 million tons. Cotton is one of the most important agricultural products produced in the USA (Agriculture in the Classroom, 2021). In terms of cotton production, the USA, a developed country, carries out production using capital-intensive techniques (Özer and İlkdoğan, 2013). The USA is followed by other cotton-producing countries such as Brazil, Pakistan, and Uzbekistan, respectively. Türkiye, which has a significant share of cotton production, ranks 7th in world seed cotton production (Table 1).

Cotton production is an important source of income and fiber for Pakistan (Nadeem et al., 2014). The most important agricultural product produced in Pakistan after wheat is cotton, and it covers a very large area compared to other agricultural products (Imran et al., 2018; Rehman et al., 2019). There were serious decreases in planting areas and production in Pakistan in the 2020-21 season. The reasons for these decreases include variable climatic conditions, insect infestations, and government support for competing products such as sugar cane and corn (International Cotton Advisory Committee, 2021). Nadeem et al. (2014) recommends the use of advanced technologies and the correct use of subsidized inputs to increase cotton production and yield in Pakistan.

Table 1. World cotton production (thousand tons)

Countries	2016	2017	2018	2019	2020	2021
China	16.029	17.130	18.493	23.505	29.500	17.366
India	17.308	17.425	14.657	18.550	17.731	17.204
USA	10.092	12.000	11.077	12.956	9.737	11.247
Brazil	3.464	3.843	4.956	6.893	7.070	5.712
Pakistan	5.237	5.855	4.828	4.495	3.454	4.096
Uzbekistan	2.959	2.854	2.286	2.694	3.064	3.373
Türkiye	2.100	2.450	2.570	2.200	1.774	2.250
World total	67.637	73.653	70.650	82.589	81.999	72.651

Source: Food and Agriculture Organization, 2021

When the seed cotton cultivation areas in the world are examined, India leads by a large margin, accounting for nearly half (41.4%) of the world's seed cotton cultivation areas. India is followed by the USA, China, Pakistan, and Brazil, respectively. Türkiye ranks 12th in the world in cotton cultivation areas (Table 2).

Table 2. World seed cotton cultivation area (thousand ha)

Countries	2016	2017	2018	2019	2020	2021
India	10.830	12.430	12.350	16.038	12.865	13.477
USA	3.848	4.492	4.130	4.777	3.521	4.034
China	3.376	4.845	3.354	4.815	3.250	3.028
Pakistan	2.489	2.700	2.373	2.527	2.079	1.937
Brazil	996	928	1.150	1.627	1.633	1.370
Uzbekistan	1.265	1.201	1.108	1.051	1.058	1.022
Benin	419	530	600	717	620	680
Burkina Faso	655	845	473	591	647	636
Turkmenistan	550	540	535	515	535	626
Türkiye	416	501	519	478	359	432
World total	33.595	39.479	35.651	43.456	31.479	32.584

Source: Food and Agriculture Organization, 2021

In addition, developing new cotton varieties along with improving agricultural methods is important for increasing yield (Basal et al., 2019). One of the ways to increase cotton production is to increase the yield per unit area (Özdemir, 2007). China and Türkiye rank first in seed cotton yield. China is among the most important countries in terms of cotton yield per unit area (Dai and Dong, 2014). China doubled the amount of cotton purchased per unit area in 2020 compared to the previous year, but it decreased by 63% in 2021. Türkiye follows China. Türkiye ranks 2nd in the world in terms of seed cotton yield (Table 3). Türkiye's average cotton yield is well above the world average.

Table 3. World cotton yield (kg da^{-1})

Countries	2016	2017	2018	2019	2020	2021
China	475	354	551	488	908	573
Türkiye	505	489	496	460	494	521
Mexico	467	476	483	442	469	512
Australia	542	415	505	536	534	447
Brazil	348	414	431	424	433	417
World total	168	161	161	162	167	171

Source: Food and Agriculture Organization, 2021

As a result of the measures and restrictions taken with the Covid-19 epidemic in the world, it caused a decrease in cotton consumption and trade worldwide in the 2019/20 cotton production season, but an increase in stocks was observed (Özüdoğru, 2021; Agricultural Economic and Policy Development Institute, 2021). The reasons for the slowdown in consumption include the suspension of production by ginning and textile factories in order to prevent the spread of the Covid-19 pandemic. Additionally, the decrease in the workforce and, therefore, retail losses cause decreases in orders (Agricultural Economic and Policy Development Institute, 2020). Increasing concerns with the spread of the delta variant of Covid-19 continue to pose a threat to the cotton industry, and it is predicted that there may be a slowdown in the textile industry and sales due to the increase in cases despite the increase in consumption (International Cotton Advisory Committee, 2021). As the impact of Covid-19 decreases, cotton consumption is increasing. China represents 31% of the world cotton consumption, India follows with 21%, and Türkiye holds a 7% share, ranking 5th globally (Table 4).

Table 4. World domestic fiber cotton consumption (1000 tons)

Countries	2017/18	2018/19	2019/20	2020/21	2021/22
China	8.927	8.600	7.185	8.709	8.056
India	5.258	5.291	4.355	5.225	5.552
Pakistan	2.373	2.330	2.003	2.243	2.373
Bangladesh	1.633	1.568	1.502	1.764	1.851
Türkiye	1.644	1.502	1.437	1.676	1.872
Vietnam	1.437	1.524	1.437	1.589	1.502
Other countries	5.482	5.416	4.473	4.615	4.876
World total	26.754	26.230	22.392	25.822	26.082

Source: U. S. Department of Agriculture, 2022

Foreign trade has an important place in country economies. As a result of the increase in cotton consumption aroundthe world, cotton fiber has come to the fore in foreign trade (Özer and İlkdoğan, 2013). Approximately one-third of the cotton produced in the world is exported (Jacquet et al., 2022). There is a recovery in global cotton consumption and trade in the 2020–21 production season (International Cotton Advisory Committee, 2021). During the production season in question, the USA, Brazil, and India exported 3.5 million tons, 2.4 million tons, and 1.3 million tons of cotton, respectively (Table 1.5). In this season, global exports increased by 14.9% and reached 10.4 million tons

(International Cotton Advisory Committee, 2021). In the same period, the USA increased its exports by 6% compared to the previous season. Although there have been positive developments in cotton production in India, there has been a decrease in cotton exports with increasing consumption, while imports have increased by 12% in ten years (Niranjan et al., 2017). As a result of fluctuations in cotton production, a supply deficit has occurred in countries, which has caused cotton imports and exports to vary from year to year. In the 2022–23 production period, cotton exports decreased compared to the previous year, and cotton imports did not show a significant change. On the other hand, there were increases in world cotton stocks compared to the previous year (Table 5). In the 2021-22 production period, Türkiye ranks 14th in cotton exports and 6th in imports (International Cotton Advisory Committee, 2022). In cases where cotton production in the world is insufficient, stocks come into play (Özüdoğru, 2021). China, holding nearly half of the world's cotton stock, significantly influences global cotton prices (National Cotton Council, 2020).

Table 5. World cotton exports, imports, and stock status

Countries	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
World Fiber Cotton Exports (thousand tons)						
USA	3.545	3.230	3.377	3.560	3.211	2.779
Brazil	909	1.310	1.946	2.398	1.720	1.449
Australia	852	791	296	341	871	1.342
India	1.128	767	697	1.348	871	250
Benin	233	303	211	305	305	218
Greece	234	295	319	355	305	283
Mali	283	294	256	131	239	163
Other countries	1.893	2.053	1.836	2.122	2.042	1.567
World total	9.077	9.042	8.939	10.559	9.564	8.052
World Fiber Cotton Imports (thousand tons)						
China	1.243	2.099	1.554	2.800	1.785	1.357
Bangladesh	1.655	1.524	1.633	1.905	1.742	1.426
Vietnam	1.524	1.511	1.411	1.592	1.481	1.409
Türkiye	956	785	1.017	1.160	1.208	912
Pakistan	740	621	865	1.159	980	980
Indonesia	766	664	547	502	555	362
India	365	392	496	184	218	381
Other countries	1.798	1.649	1.307	1.384	1.463	1.260
World total	9.047	9.245	8.831	10.686	9.432	8.087
World Cotton Stock (thousand tons)						
China	8.272	7.766	8.034	8.546	8.138	8.143
Brazil	1.885	2.668	3.136	2.421	2.688	3.568
India	2.009	1.873	3.415	2.599	1.729	2.547
Australia	662	418	261	549	915	1.040
USA	914	1.056	1.579	686	740	925
Türkiye	425	369	602	590	622	
Other countries	2.873	3.571	4.234	3.785	3.466	4.063
World total	17.656	17.723	21.260	19.176	18.297	19.943

Source: U. S. Department of Agriculture, 2022; U. S. Department of Agriculture, 2023

Current Situation of Turkish Cotton Production

The history of cotton in Türkiye dates back to 330 BC and started to be grown by the Seljuk Turks in the 11th century (Anonymous, 2021). During the 13th and 14th centuries, the Ottoman Empire distributed cotton seeds, brought from Egypt to producers in the Aegean region, Edirne, Balıkesir, and Sinop. This initiative aimed to encourage production, provide support to cotton growers, and consequently increase cotton cultivation areas and production (Özüdoğru, 2007). With the declaration of the Republic, cotton farming gained great importance in Türkiye (Anonymous, 2021). The most grown fiber plants in Türkiye are cotton, flax, and hemp (Ministry of National Education, 2016). Cotton has an important place in our country, especially in terms of the employment and added value it provides. Cotton provides 60% of the raw materials utilized in the weaving industry (Yılmaz and Gül, 2015). Medium-fiber cotton constitutes 80-85% of the world cotton production (Ministry of National Education, 2016), and in Türkiye, all cotton produced is medium- fiber cotton (Anonymous, 2021). This type of cotton is considered an important raw material in the textile, ginning, oil, and animal feed industries (Yılmaz et al., 2005). Since labor-intensive production techniques are used in cotton agriculture (Kara et al., 2015), it is an important source of employment for Türkiye and a source of income for producers (Yılmaz et al., 2005). Its use as a raw material in both agricultural production and the textile industry makes cotton an indispensable agricultural product (Kaya, 2017). Starting from harvest, passing through different stages of the production chain such as ginning, yarn, and fabric increases the monetary value and the added value it creates (Telatar et al., 2002).

Since the lands of a few countries in the world are suitable for cotton farming, 80% of the world's cotton is produced by a limited number of countries, including Türkiye (Gençer et al., 2005; Kaynak, 2007; T.R. Ministry of Commerce, 2019; Cevheri and Şahin, 2020; Uğurlu, 2020). Türkiye ranks 7th in world cotton production, 2nd in terms of yield, and 12th in terms of cultivation areas, according to the Food and Agriculture Organization (2021). When foreign trade figures are examined, Türkiye ranks 14th in exports, 6th in imports, and 4th in stocks (International Cotton Advisory Committee, 2022). In order not to be dependent on foreign sources for cotton, which has an important place in the textile industry in Türkiye, it is important not to reduce the cultivation area, to make various regulations by making production profitable and to reduce input costs (Özdemir, 2007; Çopur and Yuka, 2016). Cotton production in Türkiye increased due to rising demand after the pandemic. According to the 2022 data of the Turkish Statistical Institute, 2.8 million tons of cotton were produced in an area of 5.7 million acres in Türkiye. 833 thousand tons of fiber cotton were obtained from the cotton produced (Table 6). In the last decade, cotton cultivation areas have increased by 21.5% and production amounts by 22.2%. The yield, which was low in previous years, peaked in 2021 and then decreased again. On the other hand, cotton cultivation areas increased by 32.6% and production increased by 22.2% in 2022 compared to the previous year.

Table 6. Cotton cultivation area, production, and yield in Türkiye

Years	Cultivated area (da)	Unseeded cotton production amount (tons)	Fiber cotton production amount (tons)	Yield (kg da^{-1})
2012	4.884.963	2.320.000	858.400	475
2013	4.508.900	2.250.000	877.500	499
2014	4.681.429	2.350.000	846.000	502
2015	4.340.134	2.050.000	738.000	472
2016	4.160.098	2.100.000	756.000	505
2017	5.018.534	2.450.000	882.000	488
2018	5.186.342	2.570.000	976.600	496
2019	4.778.681	2.200.000	814.000	460
2020	3.592.200	1.773.646	656.251	494
2021	4.322.790	2.250.000	832.500	520
2022	5.731.613	2.750.000	1.017.500	480

Source: Turkish Statistical Institute, 2022

Textile products, constituting 35% of Türkiye's exports, (Cevheri and Şahin, 2020), heavily rely on cotton as a crucial raw material. With the rapid development of the textile and ready-made clothing industry in Türkiye, cotton imports increased after the 1990s (Özdemir, 2007). In addition, the decreases in cotton production caused domestic consumption to not be met (Uğurlu, 2020). Due to these developments, a supply deficit has occurred, and Türkiye has become one of the largest cotton importing countries in the world (Semerci and Çelik, 2018; Aydoğdu et al., 2021). During the 2022–23 production period, Türkiye exported 33.6% of its cotton production to Pakistan, 12.7% to Bangladesh, 11.3% to China, and 8.3% to Vietnam. Simultaneously, Türkiye imported 30.3% from the USA, 18.6% from Greece, 17.2% from Brazil, and 10% from Australia (Agricultural Economic and Policy Development Institute, 2023). Although it is among the most produced agricultural products in Türkiye, there are many difficulties in cotton production. Some of these difficulties include high input costs, insufficient extension activities, producers' lack of record-keeping habits (Kara et al., 2015), pollution, insufficient storage, insufficient land size, changes in climate conditions, and irrigation problems

(Basal et al., 2019). In addition, problems such as those related to agricultural policies, production techniques, seeds, and varieties, problems related to harvest and post-processing, and a lack of training and cooperation among producers cause difficulties in cotton production (Gençer et al., 2005). Cotton is produced in 24 provinces in Türkiye; including Adana, Adıyaman, Antalya, Aydın, Balıkesir, Batman, Bursa, Denizli, Diyarbakır, Gaziantep, Hatay, Iğdır, İzmir, Kahramanmaraş, Kilis, Malatya, Manisa, Mardin, Mersin, Muğla, Osmaniye, Siirt, Şanlıurfa, Şırnak. It is produced in the province. In 2022, 2.8 million tons of cotton were produced in Türkiye, and 86% of this production was carried out by the provinces of Şanlıurfa, Aydın, Diyarbakır, Hatay, İzmir and Adana. When the provinces are examined in terms of cotton yield, Siirt (560 kg da^{-1}), Mardin (531 kg da^{-1}), Manisa (528 kg da^{-1}), Hatay (520 kg da^{-1}), and Izmir (520 kg da^{-1}) come first (Turkish Statistical Institute, 2022). These provinces are well above Türkiye's productivity average (475 kg da^{-1}). Şanlıurfa province, which ranks first in cotton cultivation area and production amount in Türkiye, is at a very low level with a yield of 455 kg da^{-1} per decare (Turkish Statistical Institute, 2022).

Table 7. Cotton production and cultivation area by province

Years	Şanlıurfa	Diyarbakır	Aydın	Hatay	İzmir	Adana
Cultivated area (thousand decares)						
2013	2.033	418	536	380	206	381
2014	2.184	397	589	371	235	364
2015	2.060	309	579	393	232	267
2016	1.803	332	617	440	220	273
2017	2.237	428	646	518	274	318
2018	2.314	480	537	485	277	363
2019	2.088	477	465	456	253	375
2020	1.287	404	545	332	277	230
2021	1.835	552	493	390	262	219
2022	2.425	829	574	460	333	303
Production amount (thousand tons)						
2013	948	198	287	203	118	212
2014	1.022	192	317	197	134	204
2015	916	141	287	209	121	139
2016	852	169	326	242	119	152
2017	1.028	217	331	266	144	168
2018	1.028	244	279	264	156	206
2019	813	234	246	220	142	206
2020	567	218	272	175	149	123
2021	893	309	265	210	151	114
2022	1.103	408	284	239	173	144
Yield (kg da^{-1})						
2013	466	473	535	533	574	556
2014	471	483	538	530	569	562
2015	445	457	496	532	519	518
2016	473	510	529	551	540	555
2017	460	508	513	513	524	529
2018	444	509	520	544	563	569
2019	390	490	530	481	561	549
2020	441	539	499	527	537	535
2021	487	560	537	539	574	519
2022	455	493	494	520	520	477

Source: Turkish Statistical Institute, 2022

Sustainability

Sustainability has emerged as a response to people's concerns about the environment since the 1960s (Janker et al., 2019). The concept of sustainability, which is a political concept, is based on the Brundtland Report published by the United Nations in 1987 (Kuhlman and Farrington, 2010). According to this report, sustainable development is defined as "development that is environmentally resilient, economically feasible, and socially acceptable (Latruffe et al., 2016) that meets the needs of today without compromising the needs of future generations" (T.R. Ministry of Foreign Affairs, 2021).

The essence of the concept of sustainability, "sustainable over time" (Heinberg, 2010), is based on preventing environmental problems that arise as a result of technological and economic developments and preserving ecological balance (Tosun, 2009). This concept has been reinterpreted over time in social, environmental, and economic dimensions (Praneetvatakul et al., 2001; Kuhlman and Farrington, 2010; Pusavec et al., 2010; Latruffe et al., 2016). Issues such as environmental protection and economic growth, which affect the world today, have become increasingly important. Sustainability in agriculture also appears as a frequently mentioned concept (Janker et al., 2019). Since it is not possible for producers to increase their cultivation area and they do not have enough information about efficient energy sources, they have started to use more energy to increase the output obtained from production (Yılmaz et al., 2005). Economic sustainability entails resource-consciousness in economic studies due to the scarcity of resources. Social sustainability implies society's environmentally sensitive and conscious consumption. Environmental sustainability involves conducting activities that restore the ecological balance damaged and destroyed by humans, preserving the natural state of the environment (Yavuz, 2010).

Sustainable agriculture is a hot topic with the increasing unconscious use of natural resources in the world (Özkan and Armağan, 2019). One of the most important goals of the European Agricultural Policy is the existence of an efficient agricultural sector that uses sustainable, environmentally friendly production methods (Van Passel et al., 2006). In this context, the concept of sustainability in agricultural production is important. A standard called the Better Cotton Initiative (BCI) has been developed to ensure sustainability in cotton production. In the BCI approach, it is aimed at encouraging producers to produce at international standards by providing the technical information and equipment needed by the producer and making improvements in agricultural production (Anonymous, 2023). According to this approach, the main goal in cotton production is to cause less harm to the environment, increase the income of producers, and improve their welfare levels. According to BCI standards, farmers:

- Using fewer plant protection products,
- Being efficient in water use,
- To protect the soil structure,
- Avoiding practices that threaten natural life,
- Producing quality cotton,
- It is committed to increasing the welfare of producers (World Wide Fund for Nature, 2023b).

Encouraging producers to adhere to BCI standards aims to produce quality cotton, protect the environment, increase the producers' income, and ensure sustainability in cotton production. However, in recent times, energy consumption in the agricultural sector in Türkiye has surged, leading to various problems (Yılmaz et al., 2005). The substantial increase in energy consumption in agricultural production is attributed to the use of chemical fertilizers, agricultural tools, machines, pesticides, and electricity to boost food supply. This increase has brought about many human health and environmental problems, and the efficient use of resources used in production has become important in terms of sustainability in agricultural production.

Literature includes studies on sustainability in the production of various agricultural products (Çukur and Işın, 2008; Houshyar et al., 2012; Altıntaş et al., 2017; Demir, 2017; Tahmasebi et al., 2018; Oliveira et al., 2019) and examinations of economic, social, and environmental sustainability in businesses (Özkan and Armağan, 2019; Temel et al., 2017). However, when the literature is examined, it is seen that there are few studies on determining sustainability in cotton production. Among the studies on sustainability in cotton production and supply, Zhao and Tisdell (2009) investigated the regional and geographical features that affect the sustainability of cotton supply in China and Australia and the ways in which these countries solve sustainability problems. As a result of the study, it was determined that environmental and economic factors had significant effects on the sustainability of cotton supply in China and Australia. Uzmay et al. (2009) aimed to determine the attitudes of producers in social and economic terms regarding the decrease in cotton cultivation areas in Izmir. As a result of the study, while the level of education among social variables negatively affects the cotton production situation, the producer's cotton production experience and household size have a positive effect. In terms of economic variables, the size of the enterprise negatively affects the cotton production situation; it affects gross profit margin and premiums positively. Nadeem et al. (2014) aimed to determine the factors affecting cotton production in Pakistan. As a result of the study, they determined that resources should be improved in order to increase production. It has also been determined that the increase in land size and irrigation water will increase cotton yield, but the lack of education and inexperience of farmers negatively affect the yield. Abdalla et al. (2018) aimed to evaluate the environmental sustainability of cotton production by farmers who directly benefit from the Gezira Plan in their study. As a result of the study, they concluded that environmental sustainability in cotton production under Gezira Plan was at a medium level. In addition, the availability of sufficient irrigation water, the mixing of product residues into the soil, the use of organic fertilizers, and crop rotation contribute greatly to environmental sustainability in cotton production.

CONCLUSION AND RECOMMENDATIONS

Cotton, an industrial plant, holds significance for the country's economy due to the added value it creates and contributes significantly to agricultural production and the industrial sector in its cultivation regions. Cotton is widely produced both in the world and in Türkiye.

The rapid increase in the world population has led to changes in consumption, resulting in the swift development of the textile industry. A supply deficit has occurred due to the inability of cotton production to meet the demand for cotton in the textile sector and the low quality of the cotton produced. Therefore, Türkiye, which has 3% of the world’s cotton production, has become one of the largest importers of cotton. To prevent imports, it is crucial to establish a quality control mechanism for cotton, expand licensed warehousing, and develop quality varieties. Implementing policies that support cotton production in regions with suitable climatic conditions and soil structure, along with practices aimed at increasing yield per unit area in existing production regions, can significantly boost production.

The biggest problem in cotton production is the decline in cotton prices due to high input costs. It is important for the state to establish a base price for cotton production, considering input prices, and to ensure sustainability in production due to the pressure of the exchange rate difference on costs. In addition, the use of excessive chemical control methods in cotton production, excessive water consumption, and deterioration of the soil structure as a result of the use of multiple tillage methods have led to an increase in environmental problems. In addition, difficulties have begun to be experienced in cotton production as a result of constantly changing weather conditions, a significant shift in seasons, and the manifestation of climate change. In addition, increasing temperatures and droughts cause productivity decreases in cotton production. In order to ensure sustainability in cotton production, it is important to develop and improve the irrigation methods used in production. In addition, training, and publishing activities for producers regarding cotton production techniques will enable conscious production. In order to reduce the damage caused by chemical control to the environment, the application of biotechnical, biological, and physical control methods and the development of drought-resistant seed varieties are issues that should be emphasized in order to increase productivity and quality and ensure sustainability.

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