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TABLE of CONTENTS

International Journal of Gastronomy Research

The Common Agricultural and Food Policy of the European Union: An Assessment of its Framework, Stages and Regulations

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Abstract

Agriculture (production) and food (consumption) are two important political fields that affect each other and have direct links. Agriculture and food, which have a vital function in human life, affect many areas, especially the economy of farmers and people and are interrelated. Therefore, the Common Agricultural and Food Policy is one of the most important common policy areas for the European Union, both in terms of budget and other common policies. The importance of this common policy increases especially for the smooth and smooth functioning of the common market. In this context, this study investigates the Treaty of Rome establishing the European Economic Community of the European Union and the Common Agricultural Policy established in line with the Treaty's objective of establishing a common market. Under the influence of global and regional events, state and non-state actors have protectionist and revisionist tendencies in some political areas. The European Union, which is an important non-state actor in the international system in global and regional areas, has made protectionist-centered revisions in some political areas due to both its internal dynamics and the global and regional events in the system. One of the political areas in which the European Union has made revisions is the Common Agricultural Policy. The Common Agricultural Policy of the European Union has been updated in line with its needs, especially regarding food security and reducing greenhouse gas emissions to zero.

Keywords: Common Agricultural Policy, European Union, Common Agricultural Policy Reform, Food Policy.

Review Article / *Received: 21 December 2023, Accepted: 16 January 2024, Published Online: 22 January 2024.*

1. Introduction

The Common Agricultural Policy first emerged with the 1958 Strea Conference following the Treaties of Rome (1957) (Fearne, 1998). In the Treaty of Rome, which established the European Economic Community, the main objective of the European integration process was economic integration. Articles 38 and 47 of this treaty included provisions on the Common Agricultural Policy. These provisions cover commercial issues such as the free movement of agricultural products in the countries within the European Economic Community in the establishment of the common market, which is one of the most important stages of economic integration (Ülger, 2015).

France, the founding member of the European Economic Community, is the country with the strongest agriculture among the other member countries. Therefore, it emerged with the influence of France, which was the dominant power of the European Economic Community at that time. Later on, the Common Agricultural Policy became the most important common policy of the European Union. In this framework, half of the European Union budget was used to finance the Common Agricultural Policy (Akder, 2016).

When we look at the European integration process, it is seen that it is a dynamic structure. It provides this dynamic structure with reforms. The European Union is making the Common Agricultural Policy reforms, especially in the food system. The main reason for this is that the greenhouse gas emission in agricultural production is around 10% (EEA, 2020). At the regional level, when measured about the food system, greenhouse gas emissions increase by approximately 30% (Crippa et al., 2021).

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This study focuses on the food policy of the European Union. The European Union has established policies to ensure food security in the Common Agricultural Policy and to create a sustainable food system. In this context, the European Union has prioritized our important elements in its food policy. Firstly, the European Union is to be an agricultural and food producer at the global and regional levels. The second is to focus on environmentally sustainable methods of food policy. The third is to ensure that the food policy is harmonized with the environment and health strategy in the member states of the Union. Finally, it is to correct the complexity of food policy in the European Union. When these four elements are taken together, the European Union takes into account not only its domestic policy but also the global food system (European Union, 2023).

One of the most important issues in the food policy of the European Union is food safety. In this framework, the European Union focuses its food safety policy on four main areas of protection: food hygiene, plant health, animal health, contaminants and residues. This requires the protection of all food business operators and food importers, from farms to restaurants. Therefore, the four main areas of food safety protection must be complied with by the member states of the Union (European Union, 2023).

The European Union food safety policy aims to protect human health and consumer interests and at the same time to support the smooth functioning of the European single market. These two objectives are vital for maintaining both public health standards and economic stability within the EU (Fact Sheets on the European Union, 2023).

The "Farm to Fork" strategy, which is a continuation of the Green Deal (2019) proposal, was prepared by the European Commission in May 2020.

The European Commission is taking measures to ensure food safety with the "Farm to Table" strategy. With this strategy, the European Union endeavors to ensure a high level of food safety as well as animal and plant health. This approach includes effective control systems and regular assessments to ensure compliance with the standards of the acquis. Such measures aim to ensure an efficient internal market by balancing safety with market efficiency (European Commission, 2023).

The European Union has put the "Food Sustainability Strategy" on the agenda to ensure food safety. This strategy is designed to protect the environment, ensure the availability of healthy food for all, and at the same time secure the livelihoods of farmers. This approach takes into account the entire food system, from production to consumption and waste management, and recognizes its significant impact on the environment, health and food security (News European Parliament, 2021).

The above-mentioned policies and strategies emphasize the European Union's commitment to creating a safe, sustainable and economically viable food system that benefits both consumers and producers for the Member States of the Union.

Events in the international system, both within the internal dynamics of the European Union and globally, affect the European Union. This study investigates the Common Agricultural and Food Policy, which is one of the common policy areas affected by the European Union. In this context, this study asks the question "Under what conditions and for what reasons has the Common Agricultural and Food Policy of the European Union been revised within the framework of the historical process?".

The assumption related to the research question is that the European Union has made security-oriented revisions in the Common Agriculture and Food Policy on the issues they need both due to internal dynamics and global and regional events.

This study consists of five chapters. In the first part, the framework of the Common Agricultural Policy and Food Policy of the European Union in the context of legislation and the issues it deals with are explained. The second part provides an overview of the European Union's agricultural and food policy arrangements. In the third part, the European Union food policy has many important milestones that have shaped its current outlook. These milestones are discussed within the framework of the European Union's evolving approach to agriculture, food security and sustainable development. In the fourth section, an assessment of the practical outcomes, successes and challenges of European Union food policy is presented through some selected case studies. Finally, the future of food policy is analyzed in detail below.

2. European Union Common Agricultural Policy and Food Policy Framework

Since food policy is directly related to the Common Agricultural Policy of the European Union, the framework of the Common Agricultural Policy is first explained in this section and then food policy is discussed.

After the Treaty of Rome, the European Union tried to establish policies to ensure a sustainable transition to agriculture. These efforts were made through the Common Agricultural Policy. In the European Union, the Common Agricultural Policy is within the scope of shared authority. However, the budget and framework of the Common Agricultural Policy are largely determined by the European Union (Akder, 2016).

Environmental objectives in the Common Agricultural Policy started to be integrated into the European Union in the 2000s (Feindt, 2010). Environmental policy was included in the European Union acquis with the European Single Act. The increase in environmental awareness in the European Union with the global climate crisis has also affected the Common Agricultural Policy. As a result of this effect, environmental legislation came into force in the Common Agricultural Policy and the most important among these legislations are; "Nitrates Directive (1991), the Pesticides Regulation (1991), the Habitats Directive (1992), the Water Framework Directive (2000), and the National Emissions Ceiling Directive (2001)". These legislations include issues such as irrigation of agricultural land to address problems on human health and the environment in general (Matthews et al., 2023).

Apart from the above-mentioned legislation, the European Union has enacted legislation on food safety and consumer protection. This legislation was adopted in 2002 under the name of "General Food Law". The emergence of the law was influenced by a series of food-related epidemics at the global and regional levels. This legislation created the "Farm to Table" strategy, which covers all areas related to food (Matthews et al., 2023).

The European Union's food policy is based on production, consumption and regulation. This policy covers basic issues such as "Policy Making and Regulation, Public Health and Safety, Agricultural Policies, Trade and Market Dynamics, Environment and Ethical Issues, Consumer Rights and Information and Socio-Economic Dimensions".

European Union food policy is the policy governing the food industry. This policy covers the regulation, development and implementation of issues related to the field of food. European Union food policy is therefore designed to ensure food safety, quality and sustainability. It includes regulations on the production, processing, distribution, labeling and marketing of food (Artık, 2011).

One of the primary focal points of EU food policy is the protection of public health and consumer safety. This includes setting food safety standards, managing foodborne diseases, regulating additives and chemicals in food and ensuring that food products are safe for consumption (Çeltek, 2004).

The Common Agricultural Policy of the European Union is at the centre of food policy. The Common Agricultural Policy shapes how food is produced in the European Union, affecting everything from agricultural subsidies to environmental practices in agriculture. It aims to support farmers, promote sustainable agriculture and ensure food security (Adıgüzel, 2008).

Food policy also involves managing trade in food products both within the European Union and between the European Union and other countries. This also includes negotiating trade agreements, setting tariffs and addressing issues such as food standards and geographical indications in international trade (Eurostat, 2022).

The European Union's approach to food policy increasingly includes environmental sustainability and ethical considerations. Food policy includes not only environmental ethical issues but also the promotion of organic farming, reduction of food waste and addressing the effects of climate change on agriculture (Türkiye Başbakanlık Devlet Planlama Teşkilatı Müsteşarlığı, 2007).

In food policy, important regulations have been made especially for consumers. In these regulations, the right of consumers to have accurate information such as the content and expiry date of the food they buy has been ensured. In fact, this includes labelling laws that inform consumers about the origin, ingredients and nutritional content of food products (European Commission, 2023a).

Food policy in the European Union also addresses socio-economic issues such as the impact of farmers on food prices. The aim is to balance economic growth with social equity and fair trade practices (European Commission, 2023b).

In conclusion, the Common Agricultural and food policy in the European Union aims to ensure a safe, sustainable and fair food system for the citizens of the Member States. In order to achieve this goal, the European Union implements a series of legislations and policies. Therefore, the Common Agricultural Policy and food policy is a broad and multifaceted area.

3. Stages in the Food Policy of the European Union: Basic Policies and Regulations

Food policy in the European Union has been continuously amended and adjusted within the framework of both global and regional developments. In this section, food policy has gone through a number of stages to adapt to changing social, economic, environmental and technological realities. In this section, the main stages are explained with an overview.

The origins of the European Union's food policy date back to the aftermath of the Second World War. The main concern in this period was food security and the reconstruction process of Europe, which was damaged after the war. Therefore, the focus of food policy at that time was on increasing agricultural productivity and ensuring a stable food supply (Akder, 2016). For this reason, European countries started the integration process of Western European countries in order to ensure peace in Europe, to correct the economic structure that deteriorated after the war and to stabilize the relationship between countries. These situations have led to the reorganization of the food system in Europe, as it is directly related to all issues related to the food field in Europe.

After the Treaty of Rome, European integration, in line with the goal of establishing a common market, member countries have entered into a process of cooperation and partnership in different policy areas. In this context, the countries within the European Economic Community have taken steps to establish cooperation and partnership in the field of Common Agricultural Policy. In this framework, the Common Agricultural Policy, which became the cornerstone of the European Union food policy, was established in the early 1960s. Initially, the Common Agricultural Policy aimed to increase agricultural production, ensure a fair standard of living for farmers, stabilize markets, ensure the availability of supply and provide reasonable prices for consumers (Akder, 2016).

After the Second World War, European countries recovered with the European integration process. This recovery of European countries has strengthened especially the agricultural sector and agriculture has become the focal point of food policies. Especially at this focal point, the quality and safety of food has been emphasized. Food crises such as Bovine Spongiform Encephalopathy or mad cow disease outbreak in Europe have brought up issues related to the reorganization of food policy in the European Union. The European Union has prioritized two important issues in the food crisis that it has taken back to the agenda. The first of these issues is food safety, while the other is the implementation of food quality standards (Food and Agriculture Organization of the United Nations, 2017).

The European integration process started with six countries and has continuously expanded to strengthen the European Union within the framework of regional and global developments. These enlargements of the European Union have created a number of new challenges or opportunities for organizations and countries. Challenges or opportunities have affected not only safety and quality in European Union food policies but also competitiveness in global markets. Therefore, the legislation that the European Union has created by taking these issues into account has also included the integration of environmental sustainability in the field of food into agricultural policies (Garzon, 2006).

The European Union has increasingly focused on sustainability in its post-2010 food policies. The "Farm to Fork" strategy, which is part of the European Green Deal, is the clearest example of this focus. The strategy aims to make food systems fair, healthy and environmentally friendly. In line with this aim, the European Union has addressed reforms on issues such as reducing the environmental and climate footprint of food production, ensuring food security in the face of climate change and promoting sustainable food consumption (EuroHealth, 2019).

European Union food policies have faced various current challenges, such as climate change, biodiversity loss, sustainable use of natural resources, technological innovations (such as biotechnology and digital agriculture), and food quality and authenticity. Ongoing global trade dynamics, health considerations and consumer awareness have also significantly influenced the food policy orientations of the European Union (Akder, 2016).

Overall, food policy change in the European Union reflects a gradual shift from a primary focus on production and quantity to a more nuanced approach that balances economic, social and environmental objectives. This change poses new challenges to the European Union food policy and the European Union is trying to tackle these challenges by introducing new reforms in the field of food.

4. Political and Economic Events Shaping the European Union Agricultural Policy

The food policy of the European Union has many important milestones that have shaped its current outlook. These milestones have been realized within the framework of the European Union's evolving approach to agriculture, food security and sustainable development.

The Common Agricultural Policy has been established as one of the main policies of the European Union. As mentioned before, in general, the Common Agricultural Policy aims to increase agricultural productivity, ensure a fair standard of living for farmers, stabilize markets, ensure a safe food supply and provide reasonable prices for consumers. In line with this objective, the Common Agricultural Policy has been a central element in shaping food policy in order to maintain the agriculture and food sector of the European Union in a more systematic and orderly manner (Fearne, 1998).

The Single European Act brought the first important institutional changes in the European Coal and Steel Treaty and the Treaties of Rome. The Single European Act, which was the treaty that set 1992 as the target for the establishment of the common market, authorized the European Economic Community in a number of areas such as "Agricultural Policy" and "Environmental Policy". Therefore, the European Single Act is important in terms of laying the foundations of the single market, including the free movement of goods, which significantly affects food trade and policy within the member countries of the Union (Arat et al., 2016).

The European Single Act emerged in order to solve the problems arising after the enlargement of the European Economic Community and to set new targets. The emergence of the Single Act has led to a number of innovations and reforms in the field of agriculture and food. These innovations and reforms have had positive reflections on agriculture and food. However, the food crisis at the global and regional level has led the European Union to reconsider its food policy. In this context, the widespread outbreak of Spongiform Encephalopathy, also known as mad cow disease, in Europe has been a critical event for the European Union's food policy. The member states of the Union have implemented the reforms that the European Union has put into effect at the institutional level after this outbreak. These reforms have led to increased regulation and supervision in food safety, with stricter standards and measures to ensure meat and animal safety in general (Food and Agriculture Organization of the United Nations, 2017).

After the mad cow outbreak, the European Union tried to overcome the deficiencies in the food crisis not only with reforms but also by establishing an institution. The name of this institution is the European Food Safety Authority. The European Food Safety Authority (EFSA) was established to provide independent scientific advice and communication on risks associated with the food chain. This step of the European Union is very important in terms of institutionalizing food safety and increasing consumer confidence in food (EFSA, 2016).

The Common Agricultural Policy has undergone various reforms after the Maastricht Treaty. These reforms were put into effect through "MacSharry Reform (1992), Berlin Treaty for Agenda 2000 (1999) and Luxemburg reform (2003)". In these three reforms; quality in agriculture, environmental sustainability and rural development were included. In addition, the European Union has also implemented measures such as cross harmonization, direct payments and rural development programmes (Akder, 2016).

The European Union has enacted the Food Information for Consumers Regulation, which emphasizes that food should be labelled with a list of ingredients on the packaging, indicating the ingredients in the product and products that may cause allergies (Peterman et. al. 2023). This regulation is important in terms of clarifying food labelling for the health of consumers. In particular, the clarity and accessibility of food information on the presence of allergens, which is vital for consumer protection, has been improved following this regulation (European Commission, 2023c).

The European Union's "Farm to Table" strategy (2020) aims to reduce food waste, protect nutrition and human health, prevent food fraud and make food environmentally friendly. This strategy is important as it integrates food policy with environmental sustainability and aims to reduce the environmental impact of the food sector and contribute to climate change mitigation (European Commission, 2020).

With the "Farm to Table" strategy, the European Union has addressed and evaluated the issue of production and consumption together. It has also approached the change in production and consumption in a more holistic and coordinated manner (Matthews et al., 2023).

The EU's response to the COVID-19 pandemic, including measures to ensure the continuity of the food supply chain and support to the agricultural sector, marks a new turning point in food policy, emphasising the importance of resilience in food systems. In addition, the European Union has focused primarily on agricultural productivity and market stability, but also on food safety, sustainability, environmental issues, and consumer information and protection.

5. Crises in European Union Food Policy

The case studies provide valuable insights into the practical results, achievements and challenges of European Union food policy. Here are some notable case studies:

The Horse Meat Scandal: In 2013, it was revealed that foods purporting to contain beef were in fact made from horse meat. This scandal raised serious concerns about food labelling and traceability in the European Union. The European Union strengthened its food safety and fraud detection systems and improved traceability and testing protocols (The Guardian, 2013).

The Question of Banning Neonicotinoids to Protect Bees: Neonicotinoids, a class of insecticides, have been found to be harmful to bees, leading to a decline in their populations. The European Union Action Plan bans the outdoor use of three neonicotinoids to protect pollinators. This case highlights the European Union's commitment to environmental sustainability and its willingness to adjust agricultural practices towards ecological protection (The Economist, 2017).

Implementation of the Farm-to-Fork Strategy: The strategy aims to make the European Union food systems more sustainable. While progress has been made on food system regulations in the Strategy, there have been challenges in balancing the different interests of various stakeholders, including farmers, consumers and environmental groups. This is evidence of the European Union's commitment to integrating environmental concerns into food policy (European Commission, 2020).

Covid-19 Pandemic: The Covid-19 pandemic, which started in China in 2019 and then spread globally, has affected many areas in the European Union, especially agriculture and food. In particular, there have been problems with the "Farm to Table" strategy and the supply of agricultural and food products. The European Commission has prepared draft proposals to solve the crisis. In this draft, issues such as direct support to farmers and solving the problems of producers and consumers in the field of agriculture and food were included. Therefore, the European Union reacted quickly to the Covid-19 pandemic to solve the problems affecting the Common Agricultural and Food Policy area. However, the use of direct support in the field of agriculture and food in the member states of the Union was not deemed sufficient (European Court of Auditors, 2023).

Therefore, after the Covid-19 pandemic, the European Union has focused especially on agriculture and food. In the event of a crisis that poses risks and threats in the field of agriculture and food, the European Union has tried to create policies to reduce the problems associated with the sustainability of agriculture and food. In addition, the European Commission has proposed the opening of a "European Union Food Safety Observatory" in order to prevent similar disruptions in the event of such major crises in the future. With this proposal, the European Union aims to ensure the affordability of food and the availability of food supplies. In other words, the Observatory is intended to provide support against possible difficulties in production (agriculture) and consumption (food) (Fortuna, 2020).

Ukraine War: In the post-Cold War period, Russia and Ukraine have been at odds over many issues. These conflicts have negatively affected the relations between Russia and Ukraine. As a result, Russia first annexed Crimea in 2014. Then, in 2022, it intervened militarily to occupy Eastern Ukraine. Russia's military intervention in Ukraine has affected the European Union in the field of agriculture on the basis of the member states of the Union. Because the member states of the Union are dependent on Russia and Ukraine for food and fertilizers. After the war in Russia and Ukraine, it became difficult to import food and fertilizers from these countries, which endangered food security in the European Union. The European Union has tried to solve this problem through international cooperation. In addition, support was provided to farmers within the framework of the Common Agricultural Policy (European Commission, 2023).

These case studies illustrate the complexity of food policy in the European Union. They also reflect the dynamic nature of the food policy environment, showing how the European Union is moving forward on. issues ranging from food safety and fraud to environmental protection and trade relations.

6. The Future of Food Policy in the European Union

The Common Agricultural Policy, which was established in 1958 in line with the objectives of the Treaty of Rome of the European Union, continues to be the most important common policy area of the European Union despite all the reforms it has undergone for nearly 60 years. Since half of the European Union's budget is allocated to this policy area, it has been discussed at every stage of the European Union and in which areas the future steps should be taken (Brady et al., 2009).

In 2017, the European Commission conducted a survey entitled "Modernizing and Simplifying the Common Agricultural Policy". According to the results of this survey, the Common Agricultural Policy needs to be adapted to the conditions of the period in order to better address the problems experienced at the global and regional level. In particular, it should minimize air pollution from agricultural sources in reducing greenhouse gas emissions in the context of climate change. This is very important for human health. Therefore, the European Union needs to continuously improve issues related to human health, such as labeling of food products within the framework of food safety. It should also support local food production and consumption, such as the "Farm to Table" strategy. This support strengthens local farmers and their relationship with the market (European Commission, 2017).

The future of food policies in the European Union is poised to respond to evolving challenges and opportunities, influenced by technological advances, climate change and changing consumer preferences.

It focuses on the development of agricultural practices that are compatible with climate change, including drought-resistant crops and sustainable water management. Emphasis is placed on reducing the carbon footprint of the food sector and increasing carbon sequestration in agriculture (European Commission, 2020).

The European Commission has prepared a draft Common Agricultural Policy from 2023 to 2027. It was adopted on December 2, 2021 and entered into force on January 1, 2023. This new legislation is crucial for securing the future of agriculture and food, as well as achieving the target set in the Green Deal (European Commission, 2023d).

In the 2023-2027 Common Agricultural Policy process, the highest proportion of the European Union budget is allocated to the Common Agricultural Policy. The money allocated from this budget is committed to support projects related to scientific research and innovation, in particular to secure a sustainable agricultural sector (European Commission, 2023d).

In the new Common Agricultural Policy reform, the Union has prepared strategic plans for each of the member states to identify their specific needs. In these plans, the European Union aims to create fairer and more performance-based countries, taking into account the needs of farmers and environmental and climate objectives. However, this strategic plan does not take into account that the functioning of the common market is not impaired and that the institutions are not overburdened (Council of the European Union, 2023).

The future of food policies in the European Union is likely to be shaped by a combination of several factors that require adaptive and forward-looking policies. While the European Union's food policies will be guided by the evolving environment at the global and regional level, issues such as balancing the needs for environmental sustainability, economic sustainability and social equity will remain at the center of the European Union's focus.

7. Conclusion

As we have explored, the realm of food politics in the European Union is a dynamic and multifaceted domain, encompassing a broad range of policies, regulations, challenges, and opportunities. From the inception of the Common Agricultural Policy to the current focus on sustainable food systems under the Farm to Fork Strategy, the European Union has continually evolved and adapted its approach to food policy. This evolution reflects the EU's commitment to addressing complex issues such as food safety, environmental sustainability, public health, and socio-economic equity.

Declaration of Competing Interest

The author declares that they have no financial or non-financial competing interests.

Author's Contributions

H. Günay (0000-0003-1503-7415): *Definition, Conceptualization, Methodology, Data Collection, Writing, Editing*.

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Utilization of Bamboo *(Bambusa vulgaris)* Shoots in Fresh Pasta Noodle Production

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Abstract

This study aimed to investigate the sensory acceptability of fresh pasta noodles made from bamboo (*Bambusa vulgaris*) shoots, incorporating different proportions at 0% (control), 25%, 50%, 75%, and 100%. The sensory acceptability of the treatments was evaluated in terms of aroma, texture, appearance, and taste, as well as their overall acceptability. The study also analyzed the significant differences in sensory qualities between the experimental treatments and compared them with the control. A completely randomized design was employed, involving sixty (60) evaluators. The results indicated that the inclusion of bamboo shoot in the noodle mixture adversely affected the sensory quality, with these negative effects intensifying at higher bamboo shoot proportions. In terms of aroma, texture, appearance, and taste, the differences among the experimental treatments, with the exception of the control treatment, were not statistically significant. However, significant differences were observed in these sensory aspects when comparing the control treatment to the experimental treatments. In conclusion, the research suggests that even small quantities of high-nutritional-value bamboo shoot flour can negatively impact product quality. Future studies should focus on improving the sensory quality and shelf life of these noodles, while also exploring methods to reduce production costs.

Keywords: Bamboo shoots, *Bambusa vulgaris,* Noodles, Pasta, Sensory evaluation.

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1. Introduction

The COVID-19 pandemic has created food shortages in several nations, causing an increase in flour costs globally, and in effect, some big countries are storing such important supplies. All these occurrences, in addition to the exceptional drought in the world, contribute to a spike in flour prices both at the wholesale and retail levels. It should be noted that, in addition to supply chain interruptions, increasing transportation costs and delivery times have an impact on pricing (Azernews, 2022).

With the inflation going on around the globe, bakers in the Philippines are also striving to keep bread and pastries affordable in the face of rising grain prices. In the report of Ochave (2022), flour costs have risen by 20% to almost 50% in recent months, and flour and wheat supplies seem sufficient in the Philippines. The country is a significant importer of milling-quality wheat due to its lack of agricultural wheat production. Therefore, other alternative elements are worth exploring to help introduce low-cost food production.

Bamboo (*Bambusa vulgaris*) shoot, also known as common bamboo, is a giant tropical and subtropical clumping bamboo native to southern China and Madagascar and is a frequent element in many Asian recipes (Schröder & Link, 2021). Bamboo shoots are regarded as a delicacy for human ingestion (Bisht et al., 2018) and were a popular alternative food source even in the past. It has been reported that bamboo shoots were used in times when no other food sources were available and are considered one of the healthiest foods up to the present because of their low-fat content and high source of dietary fiber (Caasi-Lit et al., 2010; Bisht et al., 2018).

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Bamboo shoots are one of those underutilized elements in food production because bamboo is usually used in building construction, weaponry, musical instruments, and others (Yamini & Suganya, 2021). A team of researchers from Pampanga State Agricultural University has developed various value-adding products using bamboo shoots, such as bamboo shoot pickles, bamboo shoot pies, bamboo shoot oatmeal cookies, bamboo shoot empanada, and bamboo shoot muffins (Zaragoza, 2019), in order to introduce additional uses of the bamboo shoots, especially in the Philippines.

The empirical gap is highlighted in this study. Several studies have suggested that further research on the additional uses of bamboo shoots as a food source may be undertaken. Liu et al. (2018) suggested that new food products from shoots may be developed, including preservation and processing. It has been supported by Maroma (2015) that further study should be conducted to determine the suitability of bamboo shoots in various food products. Also, other suitable varieties of bamboo and unique value-added products out of them can be used (Bhavana et al., 2021). Common bamboo (*Bambusa vulgaris*) will be used in this experiment. It has been commonly used in food-related experimental research in the country (Zaragoza, 2019; Maroma, 2015).

This research aimed to determine the sensory acceptability of pasta noodles utilizing bamboo (*Bambusa vulgaris*) shoot flour. Specifically, it aims to: (1) determine the sensory qualities of bamboo shoot pasta noodles in terms of taste, appearance, texture, and aroma; (2) determine if there is a significant difference among the experimental treatments in terms of taste, appearance, texture, and aroma; and (3) determine if there is a significant difference between the control and the experimental treatments in terms of taste, appearance, texture, and aroma.

2. Literature Review

2.1. Bamboo *(Bambusa vulgaris)* Shoots

The health benefits of bamboo shoots have been scantily understood until recently (Chandramouli & Viswanath, 2015). Bamboo has diverse uses in the culinary field. The utilization of bamboo shoots has gained attention worldwide because of their potential as an alternative plantation crop and their high nutritional value and health benefits. In Behera and Balaji's (2021), they called bamboo shoots "green gold." They described bamboo shoots as magical because of their tremendous health benefits, like anti-cancer, antioxidant, anti-aging, cardio protection, weight loss, and probiotics.

Bamboo shoots are an important economic crop widely cultivated around the world. Because it exhibits potential nutraceutical effects and contains various types of bioactive components, such as carbohydrates, phenols, phytosterols, vitamins, minerals, amino acids, and prebiotic properties, and is a great source of carbon (Chen et al., 2018; Ahmad et al., 2022), it is an excellent source of nutritious food and an incredible way to ensure food security (Singhal et al., 2021).

Xu et al. (2022) reported that bamboo shoots are abundant in dietary fiber and constitute a natural, pollution-free, high-quality food source. Dietary fiber is known to facilitate digestion, provide anti-oxidation benefits, and assist in reducing blood lipid levels. However, an excessive amount of insoluble dietary fiber in bamboo shoots can result in increased lignification and hardness, yielding a coarse taste and excessive residue post-chewing, which substantially diminishes product quality and lowers consumers appeal. Fresh-cut bamboo shoots serve as primary raw materials in the production of ready-to-eat food processing. The quality of these processed foods is closely linked to the dietary fiber content of fresh-cut bamboo shoots.

2.2 Utilization of Bamboo Shoots in Other Studies

Mostly bamboo is utilized as food, the roof and walls of houses, fences, and domestic and agricultural implements such as water containers, food and drink container hats, arrows, and quivers, which has created more opportunities for innovation (Liu et al., 2018; Phimmachanh et al., 2015). Introducing new sources of food, such as bamboo, may be beneficial in addressing the hunger and malnutrition other parts of the world are experiencing (Sharma et al., 2018).

Felisberto et al. (2017) have produced bamboo shoot flour using different varieties such as *Dendrocalamus asper*, *Bambusa tuldoides*, and *Bambusa vulgaris*. The result of their experiment showed that all the bamboo shoots have low moisture content, protein, lipids, and ash contents and therefore can be processed into powder form. In Zhao et al. (2021), they used bamboo shoots as one of the ingredients in a beverage mixed with jujube fruits. The study suggested that the fermentation of red jujube fruits and bamboo shoots could be an effective way to develop a new beverage with high nutritional value, high antioxidant capacity, and high dietary fiber content. Some studies have used bamboo shoots as a fried item, as in the case of Rajchasom et al. (2019), who were able to introduce a seasoned deep-fried shredded bamboo shoot product. Behera & Balaji (2021) have fermented bamboo shoots and have seen the potential of the product economically, while past studies such as Mustafa et al. (2016) and Bajwa et al. (2018) used bamboo shoot powder to make baked items because of its tremendous health benefits. All these endeavors were rooted in efforts to look for and make use of cheaper sources of food with high nutritional content.

3. Material and Methods

3.1. Materials

The materials and equipment needed in the production process were the following: chopping board, bowls, pots, knife, strainer, tray, measuring spoon, measuring cup, rolling pin, fork, mixing bowl, and knife. All materials and equipment used were clean, thoroughly washed, sterilized, and dried as needed. Bamboo shoots were sourced and purchased from local market vendors in South Cotabato Province, Philippines.

3.2. Production of Bamboo Shoot Flour

Fresh, weighty, firm, and approximately 12-inch-tall shoots were selected for the study. After collecting the bamboo shoots, they were washed thoroughly. The outer leaves and sheaths were removed until they reached the light-colored inner layer. After which, the shots were sliced thinly, washed, boiled for 45 minutes, and drained for at least 10 minutes. After draining, the shoots were sun-dried for 3 days, from 9:00 in the morning until 4:00 in the afternoon. To completely dry the shoots, they were oven-dried for 10 min at 180°C. The dried shoots have been processed in a grinder to pulverize them and sifted out to get a finer texture.

3.3. Production of Bamboo Shoot Fresh Pasta

Ingredients for each treatment were measured, mixed, and kneaded until they became smooth. Then the dough was rested for thirty (30) minutes and covered in cling wrap. The doughs were then rolled to flatten at approximately 1 mm thick, and after flattening the dough, it was cut into strips approximately 3 millimeters wide to make fresh pasta.

3.4. Composition Experimental Treatments and Control

Five treatments shown in Table 1 were used in this experiment, which utilized a Completely Randomized Design (CRD). All treatments will be prepared following the production process, and the ratings will be analyzed using descriptive statistics and a test of difference.

3.5. Sensory Evaluators

A total of sixty respondents were comprised of the sensory evaluators of the study. By including individuals from different backgrounds and experiences, the study aimed to obtain a comprehensive understanding of the acceptability of the treatments under evaluation. The panel of evaluators was composed of students, faculty, and staff of the Joji Ilagan International School of Hotel and Tourism Management, as well as food production professionals and household mothers who were able to provide valuable practical insights.

3.6. Sensory Evaluation Procedures

Prior to the actual conduct of the research, the researchers secured permission from the School Dean of Joji Ilagan International School of Hotel and Tourism Management School Program. The in-charge of the school kitchen laboratory has also permitted the researchers to conduct the sensory evaluation on school premises.

To ensure clarity and prevent any confusion during the study, the researchers utilized small disposable containers for each treatment. Each container is appropriately labeled as Treatment 1, 2, 3, 4, and 5, signifying the different experimental treatments being tested.

Table 1. Experimental Treatments and the Control

Treatment	*Ratio*	*Composition*
T1	100% Bamboo Shoots	2 cups of Bamboo Shoots Flour *+ 3 eggs +1 tablespoon oil + 1 teaspoon salt*
T2	75% Bamboo Shoots; 25% All Purpose Flour	1½ cup Bamboo Shoots Flour + ½ cup of All Purpose Flour *+ 3 eggs +1 tablespoon oil + 1 teaspoon salt*
T3	50% Bamboo Shoots; 50% All Purpose Flour	1 cup Bamboo Shoots Flour + 1 cup of All Purpose Flour *+ 3 eggs +1 tablespoon oil + 1 teaspoon salt*
T4	25% Bamboo Shoots; 75% All Purpose Flour	½ cup Bamboo Shoots Flour + 1½ cup of All Purpose Flour *+ 3 eggs +1 tablespoon oil + 1 teaspoon salt*
T5 (Control)	100% All Purpose Flour	2 cups of All Purpose Flour *+ 3 eggs +1 tablespoon oil + 1 teaspoon salt*

For the evaluation of each treatment, evaluators were tasked with sequentially tasting them. To eliminate any lingering aftertaste from the previous treatment and to effectively distinguish between the various treatments, participants were provided with water to drink. This process was designed to guarantee accurate results by minimizing any potential carryover effects.

To facilitate the assessment process, researchers provided participants with evaluation forms and detailed instructions. The collected survey results were then checked for completeness and compiled for data analysis.

The sensory acceptability of the treatments was assessed using a 5-point hedonic scale. This scale allows participants to provide their responses based on their preferences, ranging from disliked very much (1.0–1.49) to liked very much (4.5–5.0).

3.7. Data Analysis

Once the survey forms had been gathered, the research team proceeded with the task of systematically organizing and summarizing the collected data for comprehensive analysis. The data were carefully compiled and processed statistically. Weighted means were employed to effectively describe the acceptability of each treatment, as well as the overall acceptability of all treatments.

To analyze the significant distinctions between the control group and the experimental treatments, pertaining to aroma, texture, appearance, and taste, an Analysis of Variance (ANOVA) was conducted. This statistical technique facilitates a comprehensive investigation into the variations in sensory characteristics between the control and experimental groups. By employing ANOVA, the researchers were able to determine if any statistically significant differences existed. To explore potential significant differences among the experimental treatments in relation to crucial sensory attributes such as aroma, texture, appearance, and taste, the researchers employed a Z-Test.

3.8. Ethical Considerations

Before proceeding with the sensory evaluation, the researcher ensured that all respondents were given the consent form. This form contained comprehensive information about the study, including its aims, limitations, benefits, and institutional approval. Additionally, participants were assured that their personal data has been treated confidentially, and they will have the freedom to discontinue their survey participation at any time and for any reason. Furthermore, the researchers have emphasized that participation should be voluntary. The evaluators were informed of the contents of the treatments and any health concerns that may arise from consuming the product.

4. Results and Discussion

4.1. Acceptability of the Experimental Treatments and the Control

Table 2 provides information about the general acceptability of bamboo shoot pasta noodles. The table includes ratings for various experimental treatments, as well as a control treatment (treatment 5). According to the data, all experimental treatments were rated slightly acceptable, indicating that they were generally slightly accepted by the participants or evaluators.

Table 2. Acceptability of the Experimental Treatments and the Control in Terms of the Sensory Qualities

Treatment	*Aroma*		*Texture*		*Appearance*		*Taste*	
	Mean	*Interpretation*	*Mean*	*Interpretation*	*Mean*	*Interpretation*	*Mean*	Interpretation
T1	1.83	Slightly Acceptable	1.75	Slightly Acceptable	1.75	Slightly Acceptable	1.83	Slightly Acceptable
T2	1.95	Slightly Acceptable	1.95	Slightly Acceptable	1.95	Slightly Acceptable	1.92	Slightly Acceptable
T3	2.47	Slightly Acceptable	2.37	Slightly Acceptable	2.48	Slightly Acceptable	2.42	Slightly Acceptable
T4	2.92	Moderately Acceptable	2.80	Moderately Acceptable	2.88	Slightly Acceptable	3.12	Acceptable
T5 (Control)	3.45	Moderately Acceptable	3.47	Acceptable	3.60	Acceptable	3.55	Acceptable

Legend: 4.5 – 5.0 = Highly Acceptable; 3.5 – 4.49 = Acceptable; 2.5 – 3.49 = Moderately Acceptable; 1.5 – 2.49 = Slightly Acceptable; 1.0 – 1.49 = Not Acceptable

However, the control treatment (treatment 5) received a moderately acceptable rating. The data focuses on evaluating the table further and points out that treatment 4 obtained the highest acceptability rate among all the experimental treatments. This implies that treatment 4 was considered the most acceptable option among the tested variations of bamboo shoot pasta noodles. As a result, the data suggests that treatment 4 could be recommended as the preferred option, presumably for further development or adoption.

4.2 The Significant Difference among the Experimental Treatments in Terms of Aroma, Texture, Appearance, and Taste

Table 3 shows if there is a significant difference among the experimental treatments. The p-values for aroma, texture, appearance, and taste (p=0.00) are less than the significance level ($p<0.05$). This means that there is a significant difference among the experimental treatments in terms of all their sensory qualities. Therefore, there is sufficient evidence at a significance level ($p<0.05$) that the treatments are significantly different from each other.

4.3. The Significant Difference Between the Control and the Experimental Treatments in Terms of Taste, Appearance, Texture, and Aroma

Table 4 presents the significant difference between the control and the experimental treatments in terms of taste, appearance, texture, and aroma. In terms of aroma, the z-values for pair 1, pair 2, pair 3, and pair 4 are -11.83, -11.45, -7.62, and -4.07, respectively. The z-tabular value, which represents the critical value at a specific level of significance, is 1.96 at the 0.05 level. Comparing the z-values to the z-tabular value, it is observed that the z-values are all lower than the z-tabular value. This indicates that there is no significant difference between the treatments and the control for aroma. Similarly, for texture, the z-values for the different pairs are -12.51, -12.18, -8.93, and -5.41. The z-tabular value is 1.96 at the 0.05 level. As with the aroma, all the z-values for texture are lower than the z-tabular value, suggesting no significant difference between treatment and control in terms of texture. In terms of appearance, the z-values for the pairs are -13.73, -13.11, -9.55, and -6.17. All the z-values for appearance are lower than the z-tabular value, indicating no significant difference between treatment

Table 3. Analysis of Variance (ANOVA) on the Difference in the Acceptability of Sensory Qualities among Experimental Treatments

Aroma						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	44.88	3	14.96	24.74	0.00	2.64
Within Groups	142.70	236	0.60			
Total	187.58	239				
Texture						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	39.10	3	13.03	26.15	0.00	2.64
Within Groups	117.63	236	0.50			
Total	156.73	239				
Appearance						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	47.67	3	15.89	26.93	0.00	2.64
Within Groups	139.27	236	0.59			
Total	186.93	239				
Taste						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	62.61	3	20.87	34.28	0.00	2.64
Within Groups	143.68	236	0.61			
Total	206.30	239				

There is a significant difference if p-value < 0.05.

and control regarding appearance. In terms of taste, the z-values for the pairs are -12.74, -13.41, -9.47, and -3.37. All the z-values for taste are below the z-tabular value, signifying no significant difference between treatment and control in terms of taste. In summary, based on the comparison of the z-values to the z-tabular value, it can be concluded that there is no significant difference between the treatments and the control for any of the variables: aroma, texture, appearance, and taste.

Table 4. Z-test on the between the Control and Experimental Treatments in Terms of Aroma, Texture, Appearance, and Taste

Sensory Qualities	*Treatments*	*Means*	*P(Z<=z) two-tail*
Aroma	T1	1.83	0.00
	T5	3.45	
	T2	1.95	0.00
	T5	3.45	
	T3	2.47	0.00
	T5	3.45	
	T4	2.92	0.00
	T5	3.45	
Texture	T1	1.75	0.00
	T5	3.47	
	T2	1.95	0.00
	T5	3.47	
	T3	2.37	0.00
	T5	3.47	
	T4	2.80	0.00
	T5	3.47	
Appearance	T1	1.75	0.00
	T5	3.60	
	T2	1.95	0.00
	T5	3.60	
	T3	2.48	0.00
	T5	3.60	
	T4	2.88	0.00
	T5	3.60	
Taste	T1	1.85	0.00
	T5	3.55	
	T2	1.92	0.00
	T5	3.55	
	T3	2.42	0.00
	T5	3.55	
	T4	3.12	0.00
	T5	3.55	

5. Conclusions

The results of the evaluation of the sensory qualities of bamboo shoot pasta showed fair acceptance or moderate dislike by the evaluators. This means that utilizing bamboo shoots in producing fresh pasta is generally moderately disliked; therefore, other formulations may be developed to determine the most acceptable treatment. As observed in Treatment 4, which contains the least proportion of bamboo powder, the result is still moderately disliked. This implies that even though bamboo shoots have huge potential as a food source (Bisht et al., 2018; Schröder & Link, 2021; Zaragoza, 2019), their flour form cannot be used in higher proportions or as a complete substitute for flour. The results support the observations of Vanlallani and Dhiman (2020) that a minimal proportion of bamboo shoot flour may be acceptable and may improve wheat-flour-based products' sensory quality but not exceed 6 percent of the formulation. This makes it more consistent with other results of the study, such as Santosh et al. (2018), who found that adding bamboo shoot flour to bakery products showed poor acceptability of the sensory qualities. This means that the higher the proportion of bamboo shoot flour to wheat-based flour in bakery products, the more likely it is to be unacceptable.

6. Implications

6.1. Implications to Culinary Practice

As presented in the results, the researchers recommend not completely using bamboo shoot flour as a substitute for wheat flour since bamboo shoot flour has a distinct taste and flavor that may not be desirable or compatible with certain recipes. It could alter the taste of baked goods and may not be suitable for all culinary applications. The researchers recommend the use of another technique for drying bamboo shoots to potentially enhance the flavor, texture, and overall quality of dried bamboo shoots. Treatment 4 may be used in kitchen preparations to produce bamboo shoot pasta. The ratio of bamboo shoot flour to all-purpose flour may be modified.

6.2. Implications to Research

Future researchers are recommended to identify the shelf life of bamboo shoot pasta. A lesser number of food production professionals and chefs participated in the sensory evaluation; therefore, it is suggested that a similar study be conducted with larger participants from this sector. Future researchers may conduct a cost-return analysis of bamboo shoot pasta noodles and the control treatment to identify the potential economic return of the product.

Declaration of Competing Interest

The author declare that they have no financial or non-financial competing interests.

Author's Contributions

A.M. Ibrahim (0000-0002-8010-4533): *Conceptualization, Methodology, Data Analysis, Editing, Supervision, Investigation.*
J. P. Dalupan, J. M. Dongosa, G.M. Bretaña, and R.J.S. Cajulao: *Data Collection, Investigation, Conceptualization, Writing, Methodology.*

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Effects of Various Citrus Fiber Coatings on the Color, Texture, and Sensory Properties of Chicken Nuggets

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Abstract

Wastes from the fruit juice industry are sources rich in functional compounds like dietary fiber. The present study aimed to investigate the suitability of dietary fibers derived from the orange, lemon, and grapefruit juice production wastes in the production of chicken nuggets as a coating material. In the control group, nugget samples were coated with breadcrumbs. Obtained chicken nuggets were analyzed for color, texture, pH, and sensory properties. The results indicated that the use of dietary fiber from different sources had a statistically significant effect on the pH and L^*, a^*, and b^* values of the product before and after cooking at the level of $p < 0.01$. Particularly, the use of lemon and grapefruit fiber decreased the pH value of the samples significantly, whereas the usage of grapefruit fiber increased the a^* value of both raw and cooked samples significantly. The results of the sensory analysis of the cooked samples revealed that except for salinity and juiciness, all sensory parameters were influenced significantly ($p < 0.05$) by the use of dietary fiber, and the grapefruit-coated samples had a more bitter taste compared to the other groups. In terms of overall acceptability scores, the lowest mean value was determined in the samples coated with grapefruit fiber. All texture parameters except adhesiveness and springiness were influenced by the use of different dietary fibers in cooked samples ($p < 0.05$).

Keywords: Nugget, Orange fiber, Grapefruit fiber, Lemon fiber.

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1. Introduction

Chicken meat is an important source of protein that can be purchased at a lower price. Due to its structure, it is appropriate for further processing techniques and can be used to produce a wide variety of processed meat products from chicken ham to emulsified sausage. One popular food obtained by processing chicken meat is nuggets (Talu and Kayaardı, 2012). For the production of a quality industrial nugget, 80-85% chicken breast meat and 5-10% chicken skin are used. For production at low cost, the ratio of chicken skin in the base formulation can be increased and the production can also include mechanically separated chicken meat. Depending on the recipe, a certain amount of salt, spices, phosphate and ice water can be included in this mixture. The shaped nuggets are dusted with a fine layer of flour for a better adhesion of the batter and following the battering process, the outer surface of the battered nuggets are coated with crumbs for enhanced texture and flavor (Feiner, 2006). By changing the ingredients in the nugget recipe, the product formulation can be modified and the nugget formulation can be made more functional (Khatun et al., 2022).

Fruits and vegetables naturally have many beneficial functional compounds for human health. Dietary fiber, which is among these functional compounds, positively affects consumer health and is used for improving product's technological features. In terms of its general chemical composition, chicken meat is an important source of protein and essential amino acids. Unlike plant-based products, however, due to its structure, chicken meat does not contain dietary fiber and to eliminate the deficiency, plant-based dietary fibers can be added to processed chicken products for functional purposes (Talukder, 2015).

Citrus wastes are an important source of dietary fiber. There have been many studies conducted on the

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use of fibers derived from these wastes in the formulations of highly processed products (Nieto et al., 2021). Among the processed meat products in which citrus fibers are used successfully in formulations are dry-fermented sausage (Yalınkılıç et al., 2015; 2016), non-fermented dry-cured sausage (Sayas-Barbera et al., 2012), emulsified sausage (Viuda-Martos et al., 2010), chicken patty (Abdel-Naeem et al., 2022), and chicken meatball (Kılınççeker and Yılmaz, 2019). The effects of dietary fiber sources including wheat bran (Pathera et al., 2017), green pea (Binti Mohd Zaini, 2021), and dragon fruit peel (Madane et al., 2020) were investigated in studies on the quality parameters of chicken nuggets. On the other hand, the effects of orange fiber (Golge et al., 2018) and orange albedo (Ammar, 2017) were investigated in studies on the effects of citrus fibers on nugget production. Nevertheless, there is no study that investigates the effect of using citrus fibers like lemon and grapefruit, as well as orange fiber, as coating material in nugget production on the color, texture and sensory features of the product. Therefore, this study aims to investigate the effect of heat-treated dietary fibers derived from orange, lemon, and grapefruit juice production wastes on the textural, color, and sensory features of chicken nuggets.

2. Material and Methods

2.1. Materials

All of the materials (skinned chicken breast meat, sunflower oil, spices, and salt) that were used in the study were purchased from a national gross market chain (Iğdır/Türkiye). The oranges, lemons, and grapefruits used in the production of dietary fiber were also obtained from the same market chain.

2.2. Production of dietary fibers

For dietary fiber production, the flavedo layer of lemon, orange, and grapefruit fruits was first peeled with a knife and then the juice extraction process was performed with the assistance of a juicer (Sinbo SJ-3143, Istanbul, Turkey). Following this process, the residual pulp was processed based on the method described by Fernandez-Gines et al. (2003), which resulted in the production of cooked-dried dietary fibers. Within this scope, fibers of lemon, orange and grapefruit were produced from fruit juice wastes. In total three different groups of dietary fibers were produced in the laboratory environment.

2.3. Nugget production

For the production of nuggets, chicken breast meat was used. After purchasing, the skinned chicken breast meat was brought to the meat technology laboratory under cold chain and stored in refrigerator at 2°C until use. The chicken breast meat was ground in a meat grinder (Beko Km 5024M, Istanbul, Turkey) using a 3 mm plate and the ground chicken meat was then mixed by adding 2% NaCl, 0.3% black pepper, and 0.5% garlic powder. Following the mixing process, the nugget dough was allowed to rest at 2°C for 2 hours and then proceeded to the molding process. In the molding process, manual nugget molds (Artvinli Machine, Bursa, Turkey) with a 70 mm diameter were used and the nugget dough weight was standardized as 40g. The molded nugget mixtures were coated with flour and milk-egg mixture in order, and at the last step, they were coated with breadcrumbs in the control group and lemon fiber, orange fiber and grapefruit fiber individually in the experimental groups. After the coating process, the nuggets were rested at 2°C for 1 hour and then deep-fried in sunflower oil at 175°C for 3.5 minutes. As a result, four different groups of nuggets were produced. The group coated with breadcrumbs served as the control group, while the nuggets coated with lemon fiber, orange fiber, and grapefruit fiber constituted the other groups.

2.4. Analyses

2.4.1. Color Analysis

The color measurements (L*: lightness, a*: redness, and b*: yellowness) of the raw nugget samples were determined using a colorimeter (Chroma Meter CR-400, Japan) with illuminant D65, 2° observer. Following the calibration of colorimeter, raw nugget samples were measured prior to cooking, and cooked nugget samples were measured 15 min after cooking process. The color values of the samples were measured on the outer surfaces of the nuggets. The color measurement was carried out at three replicates with five samples in each group.

2.4.2. Texture profile analysis

Cooked nugget samples were cooled to room temperature for 10 min after cooking, and the samples were analyzed with the use of a texture profile analyzer (Stable Macro System - TA.XT2I) for hardness, adhesiveness, chewiness, springiness, resilience, gumminess, and cohesiveness parameters. Five parallel measurements were taken from each sample in each replicate. The running conditions were as follows; probe: 36 mm dia aluminium radiused aacc, pre-test speed: 1.00 mm/sec, test speed: 5.00 mm/sec, posttest speed: 5.00 mm/sec, distance: 10mm, time: 5 sec, trigger force: 5.00 g, load cell: 5 kg

2.4.3. Sensory analysis

After cooking, samples were evaluated by 23 semi-trained panelists in terms of appearance, texture, odor, bitterness, saltiness, juiciness, and overall assessment parameters using a nine-point hedonic scale. The total number of semi-trained panelists who participated in three different sensory sessions was 69.

2.4.4. pH

Ten g of samples in 100 mL of distilled water were homogenized using an Ultra-Turrax (IKA Werk T 25, Germany) homogenizer, and the pH value of the samples was measured with a calibrated pH-meter (ATI ORION 420, MA 02129, USA). The pH measurement was carried out at three replicates with two samples in each group.

2.4.5. Statistical analysis

The use of dietary fiber in the study was evaluated as a factor. The experiments were performed with three replicates. The results obtained for each parameter were analyzed with one-way ANOVA, and the differences among the groups were tested with Duncan's multiple comparison test at the $p < 0.05$ level. All statistical analyses were carried out using the IBM SPSS Statistics 25 software package.

3. Results and Discussion

3.1. Color Values

Table 1 presents the L*, a*, and b* values of raw nuggets. Application of cooked-dried citrus fibers as coating material in nugget production had a very significant ($p < 0.01$) impact on the color values of the product. In fact, a statistical difference at $p < 0.05$ level was detected between the experimental groups and the control group in the L* value, an indicator of brightness, depending on the use of dietary fiber in the production of nuggets. This situation is likely due to the color substances in citrus fibers. In a similar manner to our findings, it was determined that the use of orange fiber in dry fermented sausage (Yalınkılıç et al., 2012) and lemon fiber in low-fat chicken meatballs led to a significant increase in L* value (Chappalwar et al., 2021). Regarding a* values, which give information about redness and blueness values, it was found that the highest a* value was found in nuggets produced using grapefruit fiber. On the contrary, it was found that the a* values of the products coated with lemon fiber and orange fiber were lower than the control group ($p < 0.05$). Regarding the b* values of the nuggets without heat treatment, it was also determined that higher b* values were observed due to the use of citrus fiber and the highest b* value was detected in the products coated with grapefruit fiber, as in the a* value. The samples coated with grapefruit fiber had higher a* values, which is likely due to the fact that this dietary fiber source contained more lycopene and β-carotene than oranges and lemons (Xu et al., 2006).

The L*, a*, and b* values of deep fried nuggets are presented in Table 1. It can be observed that there were statistically significant differences ($p < 0.01$) between the groups with respect to the color parameters in the cooked nuggets as in the raw product. There was a decrease in the mean values of all groups after the heat treatment with respect to L* value, while there was an increase in the mean values of a* and b* parameters independently of the group. Caramelization reaction and Maillard reaction products during deep frying process probably lead to a decrease in L* value of chicken nuggets (Ngadi et al., 2007). In terms of L* value, no statistical difference was observed between the control group and the nuggets coated with lemon

Table 1. Color values of nuggets before and after cooking

Group	*Color of uncooked product*			*Color of cooked product*		
	*L**	*a**	*b**	*L**	*a**	*b**
Control	66.53±3.61^a	3.84±1.01^c	18.81±2.95^a	55.67±2.89^b	11.13±1.21^b	37.74±1.84^a
Lemon	74.27±2.64^c	1.71±0.34^b	20.61±1.10^b	54.60±2.98^b	12.33±1.39^c	38.06±1.86^a
Orange	74.98±2.71^c	-1.36±0.34^a	29.83±1.55^c	63.17±1.12^c	7.06±1.68^a	46.54±1.16^c
Grapefruit	69.84±1.50^b	7.47±0.68^d	32.19±0.84^d	49.56±2.81^a	17.78±1.72^d	41.31±2.57^b
Significance	**	**	**	**	**	**

a-d: Any two means in the same column having the same letters in the same section are not significantly different. **$p < 0.01$.

fiber (p >0.05), while the highest value was determined in the products coated with orange fiber (p < 0.05) and the lowest value was determined in the products coated with grapefruit fiber (p < 0.05). When the a* value averages of the samples were taken into consideration, as in the raw samples, the highest average a* value was detected in the products coated with grapefruit fiber. There was no difference (p > 0.05) in the mean b* values of the heat-treated products between the products coated with lemon fiber and the control group, whereas a statistically significant difference was observed in the mean b* values of the products coated with orange and grapefruit fiber (p < 0.05). In a similar manner to our study findings, the color values of cooked chicken meatballs with apple fiber, pea fiber, and lemon fiber exhibited variability depending on the type of fiber used (Kılınççeker and Yılmaz, 2019). Furthermore, in the study conducted by Ngadi et al. (2007), it was determined that deep-frying increased the a* and b* values of chicken nuggets significantly. Another study on chicken nuggets with different protein types deep-fried in oil found that deep-frying decreased the L* value and increased the a* value of the samples, although a similar tendency was not found for the b* value (Doğan et al., 2005).

3.2. pH value

Table 2 presents the pH values of the raw nugget samples. The pH values of the raw nugget samples ranged between 5.14 and 5.98 and there were significant (p < 0.01) differences in pH values due to the use of dietary fiber. While the lowest pH value was detected in the group with lemon fiber with 5.14, a statistically significant (p < 0.05) difference was detected between the group with grapefruit fiber and the control group. It is likely that the different pH values detected in raw nugget samples are associated with the acidic compounds in the fiber type used as coating material (Ünal et al., 2022). Indeed, it has been found that the use of lemon fiber in the production of low-fat chicken meatballs decreased the pH value of the product significantly, which is similar to our findings (Chappalwar et al., 2021). Moreover, dietary fiber use in meat products can either decrease or increase the pH value of the product based on the type and source of the dietary fiber used, or it can have little effect on the pH value of the product (Choi et al., 2011).

In all deep fried groups, significant increase was observed in the mean pH values (Table 2). The lowest pH value of 5.46 was observed in the nuggets coated with lemon fiber (p < 0.01) just like the raw nuggets. Presumably, the pH increase in the heat-treated products is related to changes in the proteins in the meat layer of the nugget. In fact, denaturation of meat proteins and degradation of free amino acids take place depending on the heat treatment during cooking, and as a result, nitrogenous compounds that lead to an increase in pH are produced (Sohn and Ho, 1995; Alugwu et al., 2022). Increase in pH was also observed in another study in nugget samples, produced by the use of orange fiber, after cooking and this situation was interpreted by the alkaline compounds that emerged in the meat mixture during the heat treatment (Ammar, 2017).

Table 2. pH values of nugget samples coated with different citrus fibers before and after cooking

Group	*Uncooked Product*	*Cooked Product*
Control	5.98 ± 0.05^{c}	6.12 ± 0.05^{c}
Lemon	5.14 ± 0.66^{a}	5.46 ± 0.95^{a}
Orange	5.93 ± 0.10^{c}	6.10 ± 0.06^{c}
Grapefruit	5.40 ± 0.72^{b}	5.76 ± 0.05^{b}
Significance	**	**

a-d: Any two means in the same column having the same letters in the same section are not significantly different. **p < 0.01.

3.3. Sensory analysis

Table 3 presents the results of the sensory analysis of the deep fried nuggets. According to the scores of the samples presented to the panelists, except for salinity and juiciness parameters (p > 0.05), all parameters were significantly (p < 0.01) effected by the use of dietary fiber as coating material. In case of using dietary fibers from different sources, there may be significant differences in the sensory scores of nugget samples (Ammar, 2017; Chappalwar et al., 2021; Khatun et al., 2022). While appearance score was the highest in the samples coated with grapefruit fiber, the control group was the next highest. For texture parameter, the highest mean values were determined in the control group and nuggets coated with orange fiber (p < 0.05). On the other hand, the lowest texture value was found in the samples coated with grapefruit fiber. For the odor parameter, similar to the texture value, the lowest mean value was found in the nuggets coated with grapefruit fiber (p < 0.05), while no statistical difference was noted between the mean values of the other three groups with respect to the odor parameter (p > 0.05). Panelists who consumed the heat-treated nuggets disliked the products coated with grapefruit fiber with respect to bitterness parameter and rated the products coated with this fiber with a

Table 3. The results of sensory analysis of cooked nugget samples coated with different citrus fibers

Group	*Appearance*	*Texture*	*Odor*	*Bitterness*	*Salinity*	*Juiciness*	*Overall Assessment*
Control	5.98±1.66^{ab}	6.36±1.64^{b}	6.36±1.57^{b}	2.02±1.27^{a}	3.11±1.50^{a}	4.64±1.97^{a}	6.29±1.50^{b}
Lemon	5.64±1.57^{a}	6.00±1.70^{ab}	6.22±1.86^{b}	2.64±1.86^{a}	3.02±1.40^{a}	4.60±2.09^{a}	6.11±1.60^{b}
Orange	5.71±2.30^{a}	6.60±1.47^{b}	6.70±1.52^{b}	1.88±1.08^{a}	2.81±1.36^{a}	4.40±2.13^{a}	6.17±1.68^{b}
Grapefruit	6.56±1.83^{b}	5.51±1.82^{a}	4.91±2.26^{a}	5.84±2.74^{b}	2.67±1.45^{a}	3.89±2.22^{a}	3.61±1.82^{a}
Significance	*	*	*	*	NS	NS	*

a-d: Any two means in the same column having the same letters in the same section are not significantly different. *$p < 0.05$, **$p < 0.01$, NS: not significant.

high bitterness score ($p < 0.05$). Nevertheless, no statistical difference ($p > 0.05$) was found between the orange fiber and lemon fiber groups and the control group for bitterness values. Regarding the overall assessment parameter, it was understood that the use of grapefruit fiber in nugget production was at unacceptable levels ($p < 0.05$). Conversely, no statistical difference ($p > 0.05$) was found between the use of lemon fiber and orange fiber as coating material and the control group with respect to the overall assessment parameter. The fact that the nugget samples coated with nugget scored high on bitterness score is possibly due to the flavanone glicoside called naringin, which is found in grapefruit fiber and gives a bitter taste to the product. Because this compound imparts a bitter taste to grapefruit where it is present in high levels (Victor et al., 2018).

3.4. Texture Profile Analysis

Table 4 presents the results of texture profile analysis of the nuggets cooled at room temperature after deep fat frying. It was found that there were significant statistical differences ($p < 0.01$) between the mean values of hardness value. Whereas the lowest hardness value was determined in the control group where breadcrumbs were used as the outer coating material, all groups prepared using citrus fiber showed higher mean values in comparison to the control group ($p < 0.01$). This was probably a result of the chemical composition of the dietary fibers used in the study. Because citrus fiber sources are rich in different carbohydrate compounds, dietary fiber coated nuggets may have been harder (Wang et al., 2015). However, on the other hand, this variation may have affected the water-holding capacity of dietary fiber and thus particularly affect product texture scores (Binti Mohd Zaini et al., 2021). No statistically significant difference ($p > 0.05$) was observed between the groups with respect to adhesiveness and springiness values. Cohesiveness and resilience values were the highest mean values and gumminess and chewiness parameters were the lowest mean values in the control group ($p < 0.05$). The nugget samples coated with lemon fiber, orange fiber, and grapefruit fiber exhibited higher gumminess and chewiness values. In studies where alternative dietary fibers were used to produce chicken nuggets, significant differences between the samples with respect to texture parameters were found similar to our findings, according to the type of dietary fiber used (Pathera et al., 2017; Chappalwar et al., 2021).

Table 4. The results of texture profile analysis of cooked nuggets coated with different citrus fibers

Group	*Hardness*	*Adhesiveness*	*Springiness*	*Cohesiveness*	*Gumminess*	*Chewiness*	*Resilience*
Control	23486.64±7206.97^{a}	-1.46±1.09^{a}	0.86±0.004^{a}	0.73±0.05^{b}	16891.44±4371.49^{a}	14545.83±3603.90^{a}	0.34±0.04^{b}
Lemon	32019.94±9797.98^{ab}	-2.72±2.77^{a}	0.82±0.06^{a}	0.66±0.04^{a}	20774.77±5725.42^{ab}	17021.78±5096.07^{a}	0.29±0.02^{a}
Orange	43741.87±5635.72^{c}	2.68±2.01^{a}	0.85±0.08^{a}	0.63±0.02^{a}	27505.79±2747.54^{c}	23382.11±4261.97^{b}	0.29±0.01^{a}
Grapefruit	36188.91±5757.54^{bc}	-4.80±2.42^{a}	0.80±0.04^{a}	0.66±0.03^{a}	23901.35±2562.41^{bc}	18981.36±2490.65^{ab}	0.29±0.02^{a}
Sig.	*	*	*	*	NS	NS	*

a-d: Any two means in the same column having the same letters in the same section are not significantly different. *$p < 0.05$, **$p < 0.01$, NS: not significant

4. Conclusions

The present study investigates the usability of dietary fiber derived from the wastes of orange, lemon, and grapefruit juice production as a coating material in chicken nugget production. It was found that it is possible to successfully use orange and lemon fiber as nugget coated material, except for grapefruit fiber, which adversely affects the sensory properties of the product. The use of orange and lemon fiber as a coating material in the production of nuggets is a favorable example of converting agricultural wastes in food production into high value products. Furthermore, the health beneficial phytochemicals within the dietary fiber are delivered to the consumer via chicken nuggets, which makes chicken nuggets more functional in terms of health.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

B. Yalınkılıç (0000-0002-6195-7821): *Definition, Data Collection, Investigation Conceptualization, Writing, Methodology, Supervision, Editing.*
A. Çiğdem (0000-0002-5507-4731): *Data Collection, Conceptualization, Methodology.*

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International Journal of Gastronomy Research

An Innovative Approach in Gastronomy: Ultrasound Technology

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Abstract

Ultrasound, which uses high-frequency sound waves, induces significant physical and chemical changes in food products, making it a valuable tool for various applications. It enhances food safety, quality, and preparation efficiency by improving mass transfer, disrupting cellular structures, and accelerating chemical reactions. This review aims to explore the integration of ultrasound technology into gastronomy, emphasizing its potential impact on modern culinary practices. Firstly, ultrasound effectively reduces microbial loads and chemical residues on food surfaces, enhancing food safety. Secondly, in food processing applications, ultrasound accelerates marination processes and improves meat tenderness, with ultrasonic cutting providing precision in processing foods. Thirdly, ultrasound improves the stability of emulsions and the consistency of homogenized products. This technology's ability to create stable foams, accelerate gel formation, and extract aromatic compounds paves the way for new gastronomic discoveries. Additionally, in the realm of diagnostic and quality control, ultrasound enables rapid and non-invasive quality assessments. The primary focus areas of this review include the applications of ultrasound in decontamination, marination, tenderization, cutting, diagnostic analysis, homogenization, emulsification, dehydration, rehydration, and molecular gastronomy. This study demonstrates that ultrasound technology not only enhances the sensory and aesthetic qualities of food but also supports innovative culinary techniques in molecular gastronomy. Based on a comprehensive literature search and professional experiences, this review concludes that the integration of ultrasound in gastronomy has the potential to significantly enhance food preparation methods, contributing to more efficient, creative, and high-quality culinary experiences.

Keywords: Gastronomy, Ultrasound, Culinary, Innovative Approach.

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1. Introduction

Gastronomy, a field that has gained significant popularity in recent years, is characterized by a continuous pursuit of innovation and excellence. Chefs and culinary scientists continuously seek new ways to enhance flavor, texture, and overall dining experiences, making the integration of advanced technologies increasingly significant. Food science and technology developments directly impact gastronomic practices, contributing to greater diversity in culinary applications.

Over the past quarter-century, ultrasound technology has been the subject of numerous studies in food science and technology, contributing to many innovations and becoming increasingly integrated into production processes.

Ultrasound technology employs high-frequency sound waves to induce physical and chemical changes in food products. These sound waves create microscopic cavitation bubbles in liquids, which implode and generate intense localized energy. This process can improve mass transfer, disrupt cellular structures, and accelerate various reactions within food matrices. These capabilities make ultrasound a valuable tool for various culinary applications, including the enhancement of traditional cooking methods and the development of new gastronomic techniques.

In preparing this review study, relevant scientific resources were reviewed using a comprehensive strategy. This review aims to provide an extensive and

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objective evaluation of the integration of ultrasound technology into gastronomy based on a thorough literature search and professional experiences. By examining its scientific principles, practical applications, and benefits, this review aims to demonstrate the potential of ultrasound technology to enhance both the sensory and aesthetic qualities of food. This review also explores the integration of ultrasound technology into gastronomy, highlighting its potential for various culinary applications.

2. Ultrasound Technology

Ultrasound refers to sound waves with frequencies above 20 kHz, which are too high to be detected by the human ear. In other words, ultrasound is mechanical energy consisting of 20,000 or more sound waves per second (Mason et al., 2005). The fundamental factor responsible for the effects of ultrasonic processes in food processing is acoustic cavitation. Sequential compression and rarefaction events occur when a sound wave passes through a liquid. During the rarefaction phase, if the negative pressure exceeds the tensile strength of the liquid, microbubbles and cavities form.

These bubbles, created using high-power ultrasound, rapidly grow and collapse after a few oscillations, a phenomenon known as cavitation (Feng and Yang, 2011). Cavitation derives its effect from the concentration of acoustic energy in small volumes, resulting in extremely high localized temperatures (approximately 2000-5000°C), very high pressures (approximately 10-100 MPa), micro shock waves, and the emission of light energy, according to the hot-spot theory.

There are two types of cavitation: stable cavitation and transient cavitation. Stable cavitation occurs at relatively low ultrasonic intensities of 1-3 W/cm^2 and typically contains gas and vapor. It does not play a significant role in chemical effects. If the nonlinear oscillations of bubbles begin to grow due to acoustic and environmental factors, the bubbles may transition to transient cavitation and collapse violently. However, the intensity of these collapses is lower than that of normal transient cavitation (Santos et al., 2009; Weiss et al., 2011). Stable cavitation is generally required for processes, such as emulsification, microbial, and enzymatic deactivation. In contrast, processes like dehydration, rehydration, and degassing prefer transient cavitation. Diagnostic ultrasonic processes utilize high frequencies and low energy to avoid cavitation formation.

3. Applications of Ultrasound Technology in Gastronomy

3.1. Decontamination

Decontamination is the process of removing or inactivating harmful microorganisms, chemical contaminants, or physical contaminants from food surfaces. Microbial contamination in foods is a significant issue in food production facilities because it may lead to foodborne illnesses and severe health risks. Although chemical contamination typically does not cause acute problems, it remains a significant public health concern. Therefore, the inactivation or removal of harmful microorganisms, especially pathogens, and the elimination of physical contaminants and various chemical residues like pesticides are crucial aspects of food production (Jay, 2000).

In culinary applications, decontamination is a necessary process for ensuring food safety, reducing economic losses, and maintaining quality standards. Significant cross-contamination risks exist, especially with fresh vegetables, meat, seafood, and eggs. Ensuring the safety of these products using simple and effective methods without compromising their quality is essential. Therefore, developing new food processing techniques for culinary applications is required.

Research conducted by Kılıçlı et al. (2019) and Ertugay & Başlar (2010) has shown that ultrasound can be utilized for microbial decontamination, including the inactivation of pathogenic microorganisms. Additionally, ultrasound technology can be an effective tool for removing physical contaminants and decontaminating pesticides (Cengiz et al., 2018), either alone or in combination with various techniques. Ultrasound technology can also be used for the physical cleaning of various kitchen equipment and ensuring microbial safety.

3.2. Marination

Marination is the process of enhancing the flavor, aroma, and texture of food items, especially meats and vegetables, by soaking them in various liquid mixtures (marinades) for a specified period. This process not only imparts flavor to the food but also improves its textural quality. It is employed for multiple purposes, such as enhancing the flavor and tenderness of meats, poultry, fish, and other seafood, as well as improving the taste and making vegetables more aromatic before cooking (Raj et al., 2023).

Ultrasound technology utilizes high-frequency sound waves to allow the marinade to penetrate food more quickly and deeply. Using ultrasound technology in marination offers several advantages, including the reduction of marination time, improved flavor and aroma penetration, enhanced microbial safety, and time savings. Studies by González-González et al. (2017) and Çimen et al. (2024) have shown that ultrasonic marination of meats can be an effective alternative to conventional methods.

3.3. Tenderization

Tenderization is the process of softening meat and enhancing its eating quality, making it more tender. This procedure is significant in gastronomy and culinary practices to facilitate easier chewing and digestion of meat. Conventionally, meat tenderization is achieved using mechanical, enzymatic, chemical, or thermal methods.

Ultrasound, a non-thermal process, has the potential to be effectively utilized in meat tenderization within culinary applications. Applying ultrasound to meat induces various physical and chemical changes, thereby softening its texture and improving its eating quality. Ultrasonic tenderization works by breaking down the myofibrillar proteins that bind pieces of meat together, resulting in a more tender texture (McClements, 1996). This technique is often combined with marination, allowing the marinade to penetrate the meat while simultaneously breaking down connective tissues to soften the meat. Studies have shown that ultrasonic treatment can enhance the effectiveness of marinades by increasing their penetration depth (Shi et al., 2020). Ultrasonic tenderization can be applied independently or in conjunction with conventional methods. Typically, a treatment of 10-30 minutes with ultrasonic probes or ultrasonic water baths at 20-100 kHz is sufficient (Dong et al., 2022). However, this can vary based on the technical specifications of the ultrasound device (such as frequency, power, and volume) as well as the amount and characteristics of the product being processed.

3.4. Cutting

Cutting is performed in various ways in gastronomy and culinary applications. This process includes slicing (thin slicing), chopping (cutting into small pieces), dicing (cutting into cubes), carving (creating decorative shapes from fruits and vegetables), splitting (filleting fish or separating large pieces of meat), and julienning (cutting food into thin, matchstick-like strips). These techniques are essential for food preparation, ensuring uniformity, and enhancing presentation and flavor distribution.

Ultrasonic cutting can be applied to a variety of cutting operations in the culinary field. These methods include slicing (clean, precise slices of bakery products), portioning (accurate cuts of fish, meat, and cheese), dicing (uniform cubes from fruits, vegetables, and meats), shaping (intricate designs from soft foods), and cutting layered products (ideal for desserts and filled products without smearing or mixing layers). This technique highlights its versatility and precision in culinary practices.

Ultrasonic cutting is a technique that uses high-frequency sound waves to facilitate the cutting of food products. In this method, an ultrasonic knife or cutter operates with high-frequency vibrations to produce smooth and clean cuts. The high-frequency vibrations reduce the force required for cutting, minimizing deformation and adhesion of the food product to the cutting tool. Ultrasonic cutting can be applied to a wide range of culinary products, including bakery items (e.g., bread, pastries, pies, cakes, tarts, meringues, and biscuits), frozen products (e.g., ice cream, cream cakes, pies, and sorbets), and fresh products (fish, meat, vegetables, fruits, bread) (Rawson, 1998: 256; Taha et al., 2024).

Ultrasonic cutting is especially advantageous for foods that are challenging to cut with traditional methods, such as those that are very soft, sticky, or have multiple layers. Furthermore, ultrasonic cutting has been shown to preserve the structural integrity and quality of food items better than conventional cutting methods, as it reduces the occurrence of smearing and contamination, making it an important tool in high-precision culinary applications (Taha et al., 2024).

3.5. Dehydration

Dehydration is the process of removing water from food products to preserve them and extend their shelf life. In gastronomy, dehydration or semi-dehydration is used to create ingredients that can be used in creative culinary applications without losing their nutritional value or flavor, such as dried fruits, vegetables, and meats. This technique is also applied in various culinary preparations to enhance dishes' flavors and textures by concentrating the ingredients' natural sugars and flavors.

Ultrasonic dehydration, a novel method, utilizes high-frequency sound waves to enhance the efficiency of the dehydration process. This technique improves mass transfer, significantly reducing drying times and energy consumption. Research has shown that ultrasonic dehydration maintains the nutritional and sensory qualities of food better than traditional dehydration methods (Baslar et al., 2015; Baslar et al., 2016). For example, a study by Tekin et al. (2017) showed that ultrasonic-assisted dehydration of green beans preserved more of their antioxidant activity and color than conventional air drying methods.

3.6. Rehydration

Rehydration is the process of restoring dried food products to a state close to their original form by accelerating their water absorption. This process is essential in culinary applications, particularly for preparing dried legumes, fruits, and vegetables, making them easier to use in various dishes and optimizing preparation time. Rehydration also shortens cooking times and ensures a more homogeneous texture in foods.

Ultrasound, which improves mass transfer, significantly reduces the hydration time by allowing water to penetrate the cellular structure of food products more quickly through high-frequency sound waves. This technique shows great potential for culinary applications, effectively improving the rehydration process of dried legumes, fruits, vegetables, and similar products. In addition to shortening the water absorption process, ultrasound can also reduce the cooking time of dried legumes (Ghafoor et al., 2014).

3.7. Diagnostic

Ensuring the quality and safety of food products in gastronomy and culinary applications is paramount. Diagnostic ultrasound, a non-invasive, rapid, and accurate method, is increasingly being adopted for various applications within this field, ranging from quality control to process optimization.

The application of diagnostic ultrasound in gastronomy and culinary practices covers several crucial areas. It enhances quality control by detecting inconsistencies in texture, composition, and density of food products, ensuring uniform quality and identifying defects in fruits, vegetables, meats, and dairy products. Ultrasonic waves assess the freshness and ripeness of produce by analyzing internal structures, helping ensure fresh produce for consumers (Srivastava & Sadistap, 2018; Gaete-Garretón et al., 2005). Additionally, it analyzes the composition of food items, such as fat in meat, sugar in fruits, and moisture in grains, aiding in maintaining nutritional standards and regulatory compliance (Nazir & Azaz Ahmad Azad, 2019). Furthermore, ultrasound can be used to analyze and evaluate the quality of frying oil (Izbaim et al., 2010).

3.8. Homogenization and Emulsification

Homogenization and emulsification processes have extensive applications in food processing. Homogenization involves dispersing one liquid into another immiscible liquid in the form of small particles. This technique is applied in various food creations, ranging from dairy items to soups and sauces. Homogenization, in dairy products, disrupts fat globules, ensuring that milk remains homogeneous for an extended period and provides a smoother texture (Sharma, 2017). Ultrasonic homogenization can be used in culinary practices due to its efficiency and effectiveness. This method uses high-frequency sound waves to create intense pressure variations, leading to the disruption of particles and fat globules at a microscopic level. Ultrasonic homogenization not only ensures a finer and more stable emulsion but also helps retain the ingredients' nutritional and sensory qualities (Patist & Bates, 2008). This technique is particularly useful in creating smooth textures in sauces, soups, and beverages, enhancing the overall quality of culinary products.

On the other hand, emulsification is the process of creating a stable mixture of two immiscible liquids, typically oil and water. This process is particularly critical in emulsion applications, such as sauces, salad dressings, mayonnaise, and ice cream. Ultrasonic emulsification enhances the rapid and effective mixing of oil and water phases, producing more stable and homogeneous emulsions (Taha et al., 2020). Moreover, emulsification helps in developing the desired texture and flavor profiles in chocolates and other confections. Therefore, this method can be an alternative for achieving high-quality and consistent culinary products.

3.9. Molecular Gastronomy

Molecular gastronomy is a discipline that combines scientific principles with culinary arts to understand the physical and chemical properties of foods and develop innovative cooking techniques. Integrating ultrasound technology into these techniques opens new avenues for both scientific and gastronomic innovations. Ultrasound technology, using high-frequency sound waves, can alter the internal structure of foods, improve mass transfer, and accelerate various chemical reactions, making it a transformative tool in many areas of molecular gastronomy.

Ultrasound technology can support molecular gastronomy in processes, such as foaming, gelation, component extraction, homogenization, emulsification, marination, and tenderization. By applying high-frequency vibrations to liquids, ultrasound technology creates microbubbles, facilitating the rapid and efficient formation of light and airy foams. Ultrasonic foaming produces more stable and homogeneous foams than traditional methods, offering superior aesthetics and flavor in culinary presentations (Chemat et al., 2011).

Gel formation is a fundamental technique in molecular gastronomy. Ultrasound optimizes the gelation process by accelerating gel formation and creating more homogeneous gel structures. High-frequency sound waves enable faster dissolution of gelatin and quicker gel setting, allowing chefs to create sophisticated gel structures more rapidly and efficiently (Caporaso & Formisano, 2016).

Ultrasound is highly effective in extracting aromatic compounds from plants and spices. The technology disrupts plant cell walls, allowing faster and more efficient extraction of active compounds. This method uses less solvent and shorter processing times than traditional extraction techniques, enhancing the intensity of aromatic components (Chemat et al., 2017).

The integration of ultrasound technology into molecular gastronomy facilitates innovative applications in this field. The speed, efficiency, and quality improvements provided by ultrasonics enable chefs and food scientists to prepare more sophisticated, creative, and flavorful dishes. This integration enhances the potential of molecular gastronomy, paving the way for new and exciting discoveries in the culinary world.

4. Conclusions

The integration of ultrasound technology into gastronomy represents a significant advancement in culinary science and practice. This review has indicated that ultrasound provides various benefits and applications across various culinary processes, including decontamination, marination, tenderization, cutting, diagnostic analysis, homogenization, emulsification, dehydration, rehydration, and molecular gastronomy.

Ultrasound technology enhances food safety through effective decontamination methods, reducing microbial loads and chemical residues on food surfaces. In marination and tenderization, ultrasound accelerates the infusion of flavors and softens meat textures, thereby improving the overall quality and sensory attributes of food. The precision and efficiency of ultrasonic cutting make it ideal for processing delicate and multilayered foods, ensuring clean cuts and preserving food integrity. In diagnostic applications, ultrasound allows for non-invasive, rapid, and accurate assessments of food quality, including texture, composition, and ripeness. The innovative use of ultrasound in dehydration and rehydration processes optimizes drying times and improves the reconstitution of dried foods, preserving their nutritional and sensory qualities. Furthermore, ultrasonic homogenization and emulsification enhance the stability and consistency of emulsions, which is crucial for creating high-quality sauces, dressings, and dairy products. In the realm of molecular gastronomy, ultrasound opens new avenues for creativity, enabling chefs to develop unique textures, flavors, and presentations through techniques, such as foaming, gelation, and component extraction.

This study highlights the potential of ultrasound technology in gastronomy. Its ability to induce physical and chemical changes in food through high-frequency sound waves makes it an invaluable tool for modern culinary applications. As the technology continues to evolve, ultrasound is expected to revolutionize gastronomic practices further, leading to more innovative, efficient, and high-quality food preparation methods.

In conclusion, the integration of ultrasound technology in gastronomy not only enhances the sensory and aesthetic qualities of food but also contributes to the development of safer, more efficient, and more creative culinary techniques. Future research and continued integration of ultrasound technology will undoubtedly expand its applications, offering exciting opportunities for culinary scientists and chefs to push the boundaries of modern gastronomy. Thus, while ultrasound technology stands as a pivotal advancement poised to redefine the future of culinary arts, further research is essential to fully understand and maximize its potential in gastronomic applications.

Declaration of Competing Interest

The author declares that they have no financial or non-financial competing interests.

Author’s Contributions

M. Başlar (0000-0002-8369-0769): *Definition, Data Collection, Investigation, Conceptualization, Writing, Methodology, Supervision, Editing.*

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Psychrotrophic Bacteria and Yeast Populations in Turkish White and Tulum Cheeses

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Abstract

In this study, pH and microbiological (psychrotrophic bacteria and yeast) properties of White and Tulum cheeses were investigated. According to the results of our study, the lowest pH value identified was 4.42, and the highest pH was 5.84 in the cheese samples. Psychrotrophic bacteria counts ranged from 4.15 to 6.21 log CFU/g for White cheese and 4.02 to 6.15 log CFU/g for Tulum cheese. Psychrotrophic yeast counts ranged from 2.98 to 7.58 log CFU/g for White cheese and 2.99 to 6.77 log CFU/g for Tulum cheese. The highest values of psychrotrophic yeast were detected in the Tulum cheese samples. As a result, it was determined that the numbers of psychrotrophic bacteria and yeast were high in both Tulum and White cheese samples. These high numbers of psychrotrophic microorganisms during cheese storage in the refrigerator may increase even further and reduce shelf life. To extend the shelf life of these cheeses, it is recommended to ensure hygienic handling practices and explore the use of natural preservatives or modified atmosphere packaging.

Keywords: Bacteria, Yeast, Psychrotrophic, Tulum cheese, White cheese.

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1. Introduction

Cheese is a dairy product that is widely consumed around the world. It contains high quality proteins, fat, minerals and vitamins. It also contains essential amino acids, which are considered essential and must be taken from external sources. As cheese is a concentrated nutrient, it has more compounds such as protein, fat and vitamins than milk. It is also rich in calcium and phosphorus (Hayaloğlu & Özer, 2011; Üçüncü, 2008).

In case the proper hygienic and technological conditions are not followed during cheese production, the microorganisms and their metabolites that contaminate the cheese can make this very healthy product harmful. All the molds that were isolated from moldy cheese (blue cheese) samples were species of *Penicillium* and *Aspergillus*. Toxic molds are able to alter the majority of foodstuffs, and cheese is one of the most important of them. Under optimal fermentation conditions, molds derived primary metabolites are beneficial in the production of various fermented products. Secondary metabolites known as mycotoxins, on the other hand, lead to economic damages and health problems (Özkalp & Durak, 1998).

Another classification of microorganisms based on their temperature requirements is psychrotrophic microorganisms. They are microorganisms that show the ability to flourish at temperatures of 7°C or lower and are commonly found in water, soil, plants, animal products in nature. Important psychrotrophic bacteria include bacteria such as *Pseudomonas, Acinetobacter, Alcaligenes, Flavobacterium* (Akan et al., 2014).

In order to prevent psychrotrophic bacteria from contaminating milk, hygiene should be paid attention. Since psychrotrophic bacteria lead to economic loss, complicate the processing of milk, have pathogenic effects on processed products and shorten the storage period, they are the microorganisms that need attention. In pasteurization (65-69 °C for 15 s), Gram-negative psychrotrophic bacteria are decreased by 77-97%, whereas Gram-positive bacteria may still be found in the environment. It has been noted that when the number of bacteria does not exceed 10^6 CFU/g, there is no problem (Akan et al., 2014). This study is

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aimed to identify the psychrotrophic bacteria and yeast populations in White and Tulum Cheeses, which are produced and consumed widely in Türkiye.

2. Material and Methods

2.1. Material

White cheeses were collected from 10 different sellers in Kayseri market as material in this study. Tulum cheeses were collected from Tunceli, Erzincan and Elazığ provinces of Eastern Anatolia Region of Türkiye. Each sample was transported to the laboratory under refrigerated conditions (4°C).

2.2. pH

After weighing 10 g of each cheese sample, 100 ml of distilled water was added. Afterwards, the samples were homogenized in Ultraturrax (IKA T18 Basic, Germany). Samples homogenized were measured with a calibrated pH meter (WTW, Inolab 720, Germany) (Ayar et al., 2023; Ozturk et al., 2021).

2.3. Microbiological Analysis of Cheese Samples

The samples were brought to the laboratory in sterile packages and 10 g samples were placed in a stomacher bag under sterile conditions. Then 90 ml of sterile Ringer's solution (Merck) was added and homogenized in Stomacher for 1 min. Subsequently, serial dilutions up to 106 were prepared (Sagdic et al., 2010).

2.4. Enumeration of Psychrotrophic Bacteria

For determination of psychrotrophic bacteria counts, Plate Count Agar (PCA, Merck) was used. Suitable dilutions were inoculated on PCA medium by using the spread plate method and the petri dishes were incubated at 4°C for 10 days. After incubation, the colonies were counted and the results were given as log CFU/g (Munsch-Alatossava & Alatossava, 2006).

2.5. Enumeration of Psychrotrophic Yeast

To determine the number of psychrotrophic yeasts in cheese samples, Dichloran Rose Bengal Chloramphenicol Agar (DRBC, Merck) was used. Suitable dilutions were inoculated on DRBC Agar medium using the spread plate method and the petri dishes were incubated at 4°C for 10 days. After incubation, colonies were counted and the results were given as log CFU/g (Kobatake et al., 1992).

2.6. Statistical Analysis

The statistical analysis of the cheese samples was conducted using the SPSS 18 software package. A one-way analysis of variance (ANOVA) was performed to determine the differences between the samples. Subsequently, Duncan's multiple range test was applied to identify significant differences at the 0.05 significance level.

3. Results and Discussion

The pH values of Tulum and White cheese samples are given in Table 1. The pH values of Tulum cheese samples ranged between pH 4.82-5.84. It was determined that the pH values were pH<5 especially in TC4 and TC6 samples. In addition, pH values of other Tulum cheese samples were found to be pH>5 as shown in the related table.

The pH values of TC2 and TC9 samples were higher than the other samples. The pH values of WC1, WC2 and WC7 samples were pH 5.12, 5.10 and 5.10, respectively. In the other White cheese samples were observed to have pH<5 and WC8 sample had the smallest pH with pH 4.42.

Table 1. pH values of Cheese Samples

Tulum Cheese		*White Cheese*	
Sample	*pH*	*Sample*	*pH*
TC1	5.19±0.08^{cd}	WC1	5.12±0.02^{f}
TC2	5.63±0.06^{e}	WC2	5.10±0.02^{f}
TC3	5.26±0.05^{d}	WC3	4.55±0.05^{b}
TC4	4.96±0.04^{b}	WC4	4.67±0.04^{c}
TC5	5.17±0.05^{c}	WC5	4.88±0.18^{de}
TC6	4.82±0.01^{a}	WC6	4.78±0.04^{cd}
TC7	5.00±0.04^{b}	WC7	5.10±0.11^{f}
TC8	5.03±0.05^{b}	WC8	4.42±0.05^{a}
TC9	5.84±0.05^{f}	WC9	4.96±0.08^{e}
TC10	5.16±0.08^{c}	WC10	4.72±0.10^{c}

TC: Tulum cheese, WC: White cheese, Values with the same letters in the columns are not significantly different at the 0.05 level.

The psychrotrophic bacteria counts of Tulum cheeses and White cheeses are given in Table 2. The psychrotrophic bacteria counts ranged between 4.59 and 6.21 log CFU/g in the Tulum cheese and between 4.02 and 7.40 log CFU/g in the White cheese. The TC3 sample contained the least psychrotrophic bacteria with 4.59 log CFU/g. The highest level of psychrotrophic bacteria was observed in the TC2 sample as 6.21 log CFU/g. The lowest number of psychrotrophic bacteria among the White cheese samples was found in the WC8 sample, while the highest was 7.40 log CFU/g in the WC4 sample.

Table 2. Psychrotrophic Bacteria Count of Cheese Samples (log CFU/g)

Tulum Cheese		*White Cheese*	
Sample	*Bacteria Count (log CFU/g)*	*Sample*	*Bacteria Count (log CFU/g)*
TC1	4.89±0.27^{ab}	WC1	4.09±0.20^{a}
TC2	6.21±0.09^{d}	WC2	6.09±0.05^{c}
TC3	4.59±0.16^{a}	WC3	5.51±0.15^{b}
TC4	5.40±0.20^{c}	WC4	7.40±0.08^{d}
TC5	4.65±0.07^{a}	WC5	4.11±0.07^{a}
TC6	5.13±0.25^{bc}	WC6	4.11±0.10^{a}
TC7	4.85±0.21^{ab}	WC7	6.15±0.04^{c}
TC8	5.17±0.08^{bc}	WC8	4.02±0.05^{a}
TC9	5.31±0.11^{c}	WC9	6.11±0.05^{c}
TC10	5.44±0.07^{c}	WC10	5.73±0.15^{b}

TC: Tulum cheese, WC: White cheese, Values with the same letters in the columns are not significantly different at the 0.05 level.

The psychrotrophic yeast results of White and Tulum cheeses are presented in Table 3. Psychrotrophic yeasts counts of Tulum and White cheeses were in the range of 2.98-7.58 log CFU/g and 2.99-6.77 log CFU/g, respectively. The psychrotrophic yeasts were 2.98 log CFU/g in TC3 sample and 7.58 log CFU/g in TC9 sample. The lowest number of psychrotrophic yeasts was determined in WC1 sample with 2.99 log CFU/g, while the highest number of yeasts was determined in WC2 sample with 6.77 log CFU/g. In general, it was identified that the counts of psychrotrophic yeast in the samples had high values. It is observed that psychrotrophic yeast counts of Tulum cheeses had more than White cheeses. The WC1 and TC3 samples were found to have psychrotrophic yeast <3 log CFU/g.

In the different studies, it was determined that the pH values of White cheeses were pH 4.84 (Sağun et al., 2001), pH 4.50 (Güler & Uraz, 2004), pH 4.88-4.96 (Öner et al., 2006), pH 4.6-5.3 (Cinbaş & Kılıç, 2005). These results are in line with the pH values found in our study. It was found that the numbers of psychrophilic bacteria in fresh White cheese samples sold in Elazığ were 1.5×10^{2}-8.3×10^{4} CFU/g (Dığrak et al., 1996). Another study on home-made cheese samples produced in Muğla showed that the numbers of psychrophilic bacteria were between 3.2×10^{3} and 2.5×10^{5} CFU/g (Uğur 2001). The counts of psychrophile bacteria in Afyon Tulum cheeses were determined as 3.22-4.57 log CFU/g (Kara & Akkaya, 2015).

Table 3. Psychrotrophic Yeast Count of Cheese Samples (log CFU/g)

Tulum Cheese		*White Cheese*	
Sample	*Yeast Count (log CFU/g)*	*Sample*	*Yeast Count (log CFU/g)*
TC1	6.09±0.03^{de}	WC1	2.99±0.12^{a}
TC2	6.16±0.04^{ef}	WC2	6.77±0.06^{f}
TC3	2.98±0.03^{a}	WC3	4.39±0.12^{c}
TC4	5.90±0.02^{d}	WC4	6.27±0.01^{g}
TC5	4.17±0.24^{c}	WC5	6.01±0.03^{ef}
TC6	3.39±0.12^{b}	WC6	4.02±0.09^{b}
TC7	4.22±0.02^{c}	WC7	5.78±0.04^{d}
TC8	6.38±0.03^{f}	WC8	6.23±0.02^{g}
TC9	7.58±0.14^{g}	WC9	5.87±0.10^{de}
TC10	7.54±0.01^{g}	WC10	6.11±0.04^{fg}

TC: Tulum cheese, WC: White cheese, Values with the same letters in the columns are not significantly different at the 0.05 level.

In the TS 591 Standard for White cheese, the number of yeasts and molds permitted was set as 10^{3} CFU/g (TSE, 1995). If the number of yeasts is above the relevant TSE standard, it may indicate that hygienic conditions are not maintained in the period from milking to marketing of cheese. Yeast and mold that can be present in cheese can be a minimum of 102 CFU/g and a maximum of 10^{3} CFU/g. There is no limit defined in the standard for psychrotrophic bacteria.

4. Conclusions

A significant population of psychrotrophic bacteria and yeast has been observed in Tulum and White cheeses consumed in the Türkiye. The poor hygiene conditions of production affect the microbial load in cheeses. A high number of psychrotrophic microorganisms will adversely affect the cheese shelf life. It is important to take into account that the number of psychrotrophic bacteria and yeasts may increase due to the equipment, water, personnel, air and other contamination sources used during the cheese production process.

To mitigate these effects and extend the shelf life of these cheeses, it is recommended to ensure strict hygienic handling practices and explore the use of natural preservatives or modified atmosphere packaging to control psychrotrophic microorganism growth. Implementing these measures can significantly reduce microbial contamination and enhance the safety and quality of cheese products.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

S.B. Tunaydin, S. Güvercin, A. Ervan: *Definition, Data Collection, Investigation, Methodology.*
İ. Öztürk (0000-0003-1434-4763): *Definition, Investigation Conceptualization, Writing, Editing, Methodology, Supervision.*

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