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CONTENTS

Evaluation of The Use of De-Oiled Sunflower Meal Protein Powder in Mini Frankfurter-Type Chicken Sausage

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Abstract

This research aimed to evaluate the effect of the protein powder (SPP) obtained from de-oiled sunflower meal, a by-product of sunflower oil extraction, on the physicochemical, textural, and sensory properties of mini frankfurter-type chicken sausage. The extracted proteins from the sunflower meal were added to the sausage formulation at 1% concentration, and the SPP-added sausage sample was compared with the control sample. The incorporation of SPP increased hardness, chewiness, and cohesiveness properties compared to the control sausages and slightly improved sensory attributes. The results suggest that SPP may serve as a promising ingredient to improve the quality parameters of emulsified meat products.

Keywords: Protein powder, sunflower meal, by-product valorisation, chicken sausage

Research Article
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INTRODUCTION

Due to the modern lifestyle, more people consume processed meat products such as beef or chicken sausages. In addition, customers favor consuming products with enhanced sensory, nutritional, and health attributes while having minimal effect on the environment (Ghafouri-Oskuei et al., 2020). Plant proteins have been gaining attention due to the drawbacks resulting from production of animal proteins (i.e., depletion of environmental resources) (Ermis et al., 2023; Wang et al., 2023). Plant proteins' technological properties and nutritional benefits may improve the textural and nutritional properties of emulsified meat products such as sausages.

After palm, soybean, and rapeseed, sunflower is the fourth crop in the world used to produce oil (Grasso et al., 2020). Sunflower meal, the remaining part (up to 36% of the seed) after extracting oil, has the potential to be consumed by humans (Salgado et al., 2012) while being primarily utilized as animal feed (Anal, 2017). Due to low amounts of antinutritive compounds, high protein content (around 35%), and no toxic substances found in de-oiled sunflower meal, it can be utilized as a promising source of proteins (de Oliveira Filho and Egea, 2021; Kaur and Ghoshal, 2022).

Previous studies report that sunflower proteins have comparable or superior emulsifying characteristics to egg powder, soy proteins, skim milk powder, and can form stable emulsions (González-Pérez and Vereijken, 2007; Shchekoldina and Aider, 2012; Pickardt et al., 2015). The spray drying technique is known as inexpensive and available in continuous and industrial production. Drying into powder preserves the nutritional, physicochemical, and organoleptic properties of proteins as well as improves the shelf life (Amagliani et al., 2016; Ermiş and Karasu, 2020; Khanji et al., 2018). Previous studies have reported the use of several plant-based ingredients, such as cold-pressed hazelnut cake (Atalar et al., 2023), flaxseed and tomato powders (Ghafouri-Oskuei et al., 2020), and sunflower seed flour (Grasso et al., 2020) in sausage products. However, to our knowledge, no study in the literature has reported the effects of spray-dried sunflower meal protein (SPP) in frankfurter-type chicken sausage formulation.

The objective of this study was to investigate the effect of SPP on the physicochemical characteristics and sensory attributes of mini frankfurter-type chicken sausage.

MATERIAL and METHOD

Materials

The ingredients to produce sausage samples were provided by a chicken meat processing company (CP Food, Türkiye). The chemicals were obtained from a local distributor of Sigma Aldrich (Taufkirchen, Germany). All chemicals and reagents were of analytical reagent grade.

Methods

SPP production and characterization

In our previous study, we extracted the proteins from sunflower meal and produced protein powder using a pilot-scale spray dryer. The method used to obtain SPP is detailed in our previous publication (Ermiş & Karasu, 2020). The production steps are outlined in Fig. 1. The methods used for the characterization of SPP were also reported by Ermiş & Karasu (2020) previously.

Several analyses were conducted to evaluate flowability using Hausner Ratio and Angle of Repose approaches, chemical functional groups using FTIR, thermal properties using DSC, emulsion activity index (EAI), emulsion stability index (ESI), solubility, and wettability. In addition, SEM images were obtained to analyze the microstructure of the SPP particles. The analyses conducted for SPP characterization, including the methodologies and instrumentation employed, along with the experimental data obtained, are comprehensively detailed in our previously published paper (Ermiş and Karasu, 2020). These data are not reiterated in the present study to avoid redundancy.

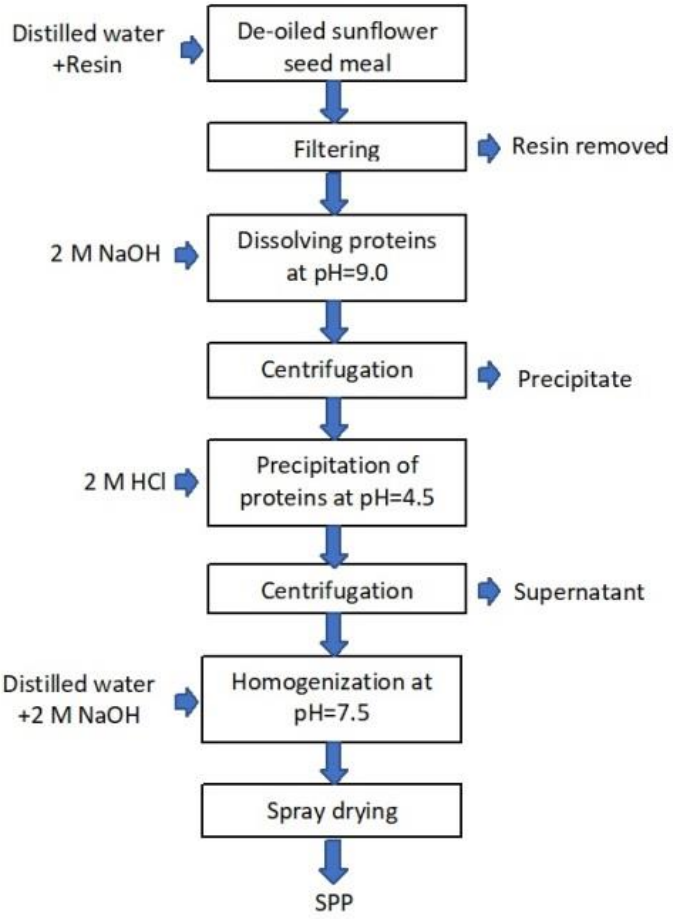

Figure 1. Protein powder production steps

Preparation of sausage samples

Frankfurter-type mini chicken sausage samples were prepared according to the method described by Peña-Saldarriaga et al. (2020) with modifications. The ingredients utilized comprised chicken breast meat, ice, water, spice mixture, wheat flour, starch, salt, sodium acetate, sodium nitrite, sodium polyphosphate, sodium ascorbate, carmine, and celery powder. 1% SPP (w/w) was added to the formulation to evaluate the effect of SPP on some quality attributes of sausage samples. 1% concentration was suggested by Atalar et al. (2023) to get optimized emulsion quality and stability. A control sample without SPP was also produced for comparison. The sausage samples were cooked for 90 min at 75–80 °C and kept at room temperature in closed plastic containers to reduce the heat of the samples before placing them into a refrigerator. They kept at around 4 °C until conducting the analyses.

Proximate analysis

Chemical contents were analyzed using AOAC standard methods (AOAC, 2000). Kjeldahl method and Soxhlet method were employed to analyze the protein and lipid contents, respectively. The pH was directly measured using a potentiometer (Hanna HI 2211), calibrated with pH buffer solutions of 4.0 and 7.0 at 25 °C. Sodium chloride content was analyzed according to ISO 1841-2 (1996).

Color measurement

A colorimeter (Konica Minolta, CR400, Japan) was employed to determine the instrumental color properties of sausage samples. The CIELAB space parameters given as lightness (L*), redness-greenness (a*), and yellowness-blueness (b*) were measured (Joint ISO/CIE Standard, 2019).

Textural Analysis

The textural properties of sausage samples were evaluated as described by Peña-Saldarriaga et al. (2020). Samples were sectioned into 20 mm cubic portions. The textural properties of each sample were assessed using a cylinder probe (35 mm diameter) attached to a Texture Analyzer (TA-XT2, Stable Micro System Ltd., Surrey, UK). Hardness, cohesiveness, springiness, and chewiness were determined.

Sensory analysis

Ten trained panelists took part in conducting the sensory test. The assessment used a 5-point hedonic scale (Ghafouri-Oskuei et al., 2020). Samples were cooked in a microwave for 15 s using thin slices 2-3 cm long. The sausage samples having no SPP and having 1% SPP were compared to one another. The panelists evaluated selected sensory attributes (texture, color, taste, and overall acceptability). They received water and unsalted crackers in between each sample's examination.

Statistical analysis

The mean and standard deviation values were calculated using the data obtained from the experiments performed in triplicate, where possible. The data was subjected to one-way analysis of variance (ANOVA) using Minitab 17 software, and mean was compared using Tukey's difference test at $p<0.05$.

RESULTS and DISCUSSION

Chemical, thermal and techno-functional properties of SPP

The optimized spray-drying conditions were applied by Ermiş & Karasu (2020) to produce spray-dried sunflower meal protein powder (SPP), and 30% of total proteins could be extracted and precipitated from the de-oiled sunflower meal. The techno-functional properties of SPP, such as flowability, compressibility, solubility, oil binding capacity, and emulsifying capabilities, are essential parameters that need to be investigated to design food processing and to develop new food productss (Shokri et al., 2022). Oil binding capacity (OBC) affects the techno-functional properties and taste of food products (Pickardt et al., 2015). It is necessary to ascertain and assess protein solubility because it is a significant phenomenon in terms of functional and technological features such as emulsifying and foaming capabilities (González-Pérez and Vereijken, 2007; Saeed and Cheryan, 1988). The proteins' solubility is affected by pH, and the lowest solubility was recorded at about pH 4.0 (Karayannidou et al., 2007). The surface hydrophobicity and net charge of peptides can also affect solubility (Sila et al., 2014). Wettability is also controlled by contact angles, the size of the pores between the particles, and the size of the pores themselves.

The solubility, wettability, oil binding capacity (OBC), emulsion activity index (EAI) and emulsion stability index (ESI) values were reported by Ermiş & Karasu (2020) as 3.75% at 21±2 °C at a pH of 7.0, 0.390 g water, 2.85 mLg-1, 74.70 m^2g^{-1} and 5.25%, respectively. In addition, the bulk (poured) density (ρb), tapped density (ρt), Hausner ratio (ρt/ρb), and Angle of Repose values were reported as 403 $kg.m^{-3}$, 639 $kg.m^{-3}$, 1.58 and 50º, respectively.

The OBC, EAI and ESI values of SPP are lower when compared to soy protein isolate which was studied by Zhang and Zhao (2013). Poor wettability and dispersibility are attributed to the high protein content in powders (Ji et al., 2015). The solubility of SPP in water was reported as lower when compared with the data previously reported by Pickardt et al. (2015). On the other hand, Ji et al. (2015) reported the wettability of milk protein isolate having 86% protein as 0.236 g water, which is lower than the wettability of SPP. The difference might be linked to the type of proteins, the varied sizes of protein particles, their surface characteristics, and the spaces between them. The data obtained from flowability analyses indicate cohesive attribute, and hence, poor flow behavior of SPP (Ermis et al., 2018). SEM images were used to analyze the shape and surface characteristics of protein particles (Fig. 2).

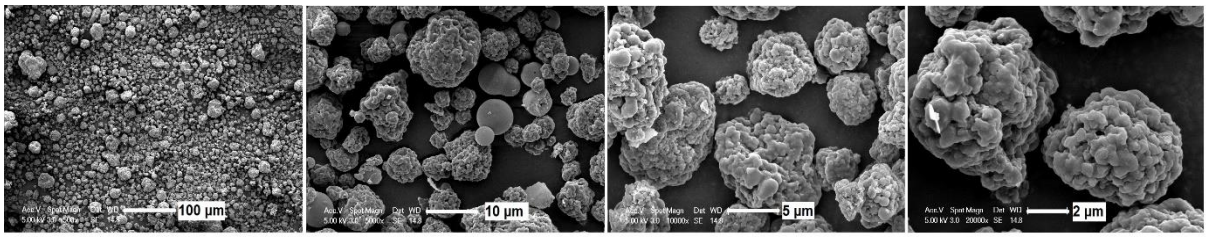

Figure 2. SEM images of SPP particles

The images exhibit different fractions of particles of different sizes. The particles possessed uneven and wrinkled surface characteristics, as seen in Fig. 2. Similar characteristics of rice protein concentrate particles were reported by Amagliani et al. (2016). Additionally, they state that spray-dried protein powders typically have particle characteristics, including uneven, cracked, hollow, wrinkled, and porous appearances.

Chemical composition and color properties of sausage samples

Table 1 displays the chemical composition of sausage samples. By adding SPP to the sausage formulation, an increase in crude protein and ash contents was noticed while fat and salt concentarions were decreased. However, no difference was observed in moisture content as a result of the addition of SPP. Ghafouri-Oskuei et al. (2020) added tomato and flaxseed powders to sausage, and they observed an increase in dry matter, protein, carbohydrate, ash, and fiber content while they reported a decrease in moisture content. Ozturk-Kerimoglu et al. (2022) report that fortification of sausage with whey protein powder resulted in an increased amount of protein. The images of SPP-added sausage sample can be seen in Fig. 3.

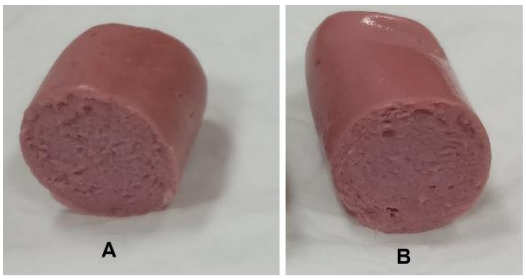

Figure 3. Images of sausage samples. A-control sample, B-SPP-added sample

The effect of SPP incorporation into chicken sausage formulation on the final product's color was evaluated. The instrumental color (L*, a*, and b*) of the sausage samples are given in Table 1. As it can be seen in the data outlined in Table 1, the protein fortification led to a slight change in color properties. The L* and a* values were decreased as a result of adding 1% SPP, while the b* value was increased by around one unit compared to the control sample. It was found that the findings of Broucke et al. (2022)) and Trindade et al. (2023) resonate with the findings of this study. Ozturk-Kerimoglu et al. (2022) found that a* and b* values were higher in whey protein-added sausage samples, while no changes were seen in the L* value. In another study, higher b* and slightly lower L* values for the samples containing soy protein were reported (Velemir et al., 2020).

Table 1. Proximate composition of sausage samples

Composition (%)	Sausage (Control)	SPP-added Sausage
Crude protein	13,69± 0.09b	14,32± 0.12a
Fat	14,29± 0.14a	13,08± 0.07b
Moisture	67,24± 0.32a	67,56± 0.21a
Salt	2,67± 0.21a	2,61± 0.19a
pH	6,24± 0.11a	6,26± 0.21a
Ash	2.2 ± 0.04b	2.4 ± 0.03a
L*	62.9 ± 0.25a	61.2 ± 0.30b
a*	28.3 ± 0.89a	27.5 ± 0.91b
b*	10.98 ± 0.66b	11.8 ± 0.58a

L* represents lightness, ranging from 0 (black) to 100 (white); a* denotes the green (negative)–red (positive) coordinate; and b* indicates the blue (negative)– yellow (positive) coordinate. Different letters within the same row depict significant differences ($p<0.05$)

Sensory evaluation results

Texture, color, taste, and overall acceptance attributes of the sausage sample containing SSP were assessed by ten trained panelists in comparison to a control sample (Table 2). It can be seen in the table that the taste, texture, color, and overall acceptance attributes of SSP-added sample had slightly higher scores compared to the control sample ($p<0.05$). Similar results were reported by Zouari et al. (2012). Their findings revealed that adding whey powder improved the sensory properties of low-fat sausage, such as flavor, firmness, and sliceability. Eyiler and Oztan (2011) observed more appetizing Frankfurter-type sausages after adding tomato powder. On the other hand, they report a decrease in the scores of flavor, odor, or overall acceptance of flaxseed powder-added sample. Similar findings are reported by Ghafouri-Oskuei et al. (2020) claiming a decrease in the general acceptance of sausage samples fortified with flaxseed powder.

Table 2. Sensory analysis scores of sausage samples

Sample	**Texture**	**Color**	**Taste**	**Overall acceptability**
Sausage (Control)	3.8 ± 0.31b	3.7 ± 0.95a	3.6 ± 0.58b	3.6 ± 0.43b
SPP-added Sausage	4.2 ± 0.73a	3.8 ± 0.56a	3.8 ± 0.49a	3.8 ± 0.22a

Different letters within the same column depict significant differences ($p<0.05$)

Textural evaluation results

The textural properties of SSP-added sausage are outlined in Table 3 compared to the control sample. The result showed a slight increase in hardness, chewiness, and cohesiveness values compared to the control sample ($p<0.05$). However, no significant change was obtained from the springiness value.

In agreement with this study's findings, fortifying chicken sausage with soy protein powder and soy protein isolate led to an increase in hardness and a firmer product (Pagthinathan and Gunasekara, 2021; Velemir et al., 2020). Similarly, adding whey powder to a low-fat sausage formulation enhanced the hardness, chewiness, and gel stress (Zouari et al., 2012). Contrary to the findings in this study, Ozturk-Kerimoglu et al. (2022) report reduced adhesiveness, chewiness, and hardness of microparticulated whey protein-added sausages.

Table 3. Textural properties of sausage samples.

Parameter	Sausage (Control)	SPP-added Sausage
Hardness (N)	17.26 ± 0.61b	19.70 ± 0.72a
Chewiness (N)	10.25 ± 0.53b	12.08 ± 0.56a
Springiness	0.97 ± 0.11a	0.97 ± 0.17a
Cohesiveness	0.82 ± 0.09b	0.83 ± 0.16a

Different letters within the same row depict significant differences ($p<0.05$)

CONCLUSION

Proteins from de-oiled sunflower meal were extracted and powdered using a pilot scale spray dryer and added into a mini frankfurter-type chicken sausage formulation. The SPP's functional, microstructural, and physical characteristics were evaluated, as well as the effect of adding SPP on the sensory and textural properties of the chicken sausage samples. The emulsifying and wettability properties of SPP were found to be satisfactory, while low solubility behavior was observed. SPP slightly increased protein and decreased fat content, while the difference in moisture, salt, and pH values was insignificant.

It was observed from the sensory study that the panel members found acceptable sensory attributes (texture, color, taste, and overall acceptance) in SPP-added sausage. In summary, the addition of SPP positively impacted the textural and overall sensory quality of mini frankfurter-type chicken sausage.

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The Negative Effects of Climate Change on Food Production in Europe

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Abstract

Food production is the source of human existence and growth and is known to be affected by global warming. Climate change significantly impacts crop yields, mainly the increased frequency of extreme climate events. Unpredictable crop output losses put our food systems at serious risk, endangering farmers and consumers everywhere. The continent of Europe is extremely sensitive to the rise in temperature brought on by climate change. Climate change forecasts throughout several European locations show consistent warming over the twenty-first century. Reducing the length of the crop-growing cycle brought on by rising temperatures is expected to result in a considerable decline in grain yield between 2050 and 2099. The average annual temperature in Europe has increased during the last three decades, while precipitation has decreased. The European Union's (EU) severe drought is thought to have reduced maize, soybean, and sunflower yields by 16%, 15%, and 12%, respectively, because most cereals are vulnerable to inadequate water as the temperature rises and an increased heat supply. Wheat exports are completely reduced when weather-related shocks or other occurrences cause disruptions in European wheat production; excessive humidity overstimulates vegetation growth, creating denser canopies and increasing the risk of plant epidemics. This review highlights how climate change negatively affects food production in Europe.

Keywords: Food production, Climate change, Europe

Review article
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INTRODUCTION

Today's world faces a significant challenge from global climate change. The average annual increase of the land and ocean temperatures since 1850 has been 0.06 °C, more than three times the rate of warming since 1982 when it was around 0.20 °C per decade. The leading causes of global warming throughout the past century include greenhouse gas emissions, fast population growth, and the use of fossil fuels (Yuan et al., 2024). Population growth rate and climate change will cause many problems for the worldwide food supply, and we will face numerous nutritional problems soon. By gradually reaching the 8 billion population on the earth, humanity is challenged to provide for the growing population's food needs (Bağdatlı et al., 2015). Increasing world population, changing climate conditions, and economic activities are growing daily, making it more important than water (Bağdatlı and Bellitürk, 2016b).

Increasing the necessary studies and measures to minimize the emissions of carbon emissions should be taken all over the world and measures that will minimize the greenhouse gas effect will play an important role in reducing the effects of global warming (Bağdatlı and Arıkan, 2020). Changing climate conditions will be an important factor in the current situation and the problems that may arise in the coming years. For this reason, solutions are needed for global warming and reducing greenhouse gases that cause climate change (Bağdatlı and Arslan, 2020).

Food production is the source of human existence and growth, and it is known to be affected by global warming (Ogunkalu, 2024; Bağdatlı et al., 2023; Elsheikh et al., 2023). Climate change and global warming are reducing the available water resources almost everywhere (Uçak and Bağdatlı, 2017). The increase in the impact of global climate change will cause global water crises between countries. Necessary measures and measures should be taken in advance to reduce the impact of global climate change (Bağdatlı and Arslan, 2019). This warming resulted in weather conditions such as flash floods, heat waves, cold waves, droughts, and strong winds. These dangerous events lead to a reduction in crop production and disrupt the ecology of an area and disease prevention and control. Furthermore, the sustainable growth of agricultural output has been impacted by climate change, which has resulted in soil degradation and a shortage of land resources (Yuan et al., 2024). Crop yields in Europe are progressively impacted by climate change, including rising temperatures, altered precipitation patterns, and an increase in extreme (Beillouin et al., 2020; Dövényi-Nagy et al., 2020 ; Oikonomou et al., 2020 ; Ben-Ari et al., 2018; Hernandez-Barrera et al., 2017; Nguyen et al., 2018). Europe's evolving climate impacts the growth of agriculture and its production potential, just like the rest of the world. It is also crucial to keep in mind that even though burning fossil fuels has the most significant influence on greenhouse gas (GHG) emissions, agriculture, the production of cereals and animals, and changes in land use brought on by agriculture, all play a significant role in climate change, contributing roughly 24% of global GHG emissions. It is becoming increasingly apparent that the effects of climate change, such as extreme weather events, are significantly influencing the world and Europe. These occurrences can affect the natural circumstances in which crops grow. In recent years, it has played a role in the decline of food security in nations that are members of the European Union. It is important to remember, though, that its member nations rank among the world's top producers of cereals. Currently, they export 15% of the world's cereal production and supply 20% of it (Łącka et al., 2024). The climate conditions for cereal production are becoming more unpredictable due to the current escalation of the global warming issue. This is especially noticeable when looking at the average annual temperature and precipitation, which show a propensity to de-regulate the conditions of agricultural ecosystems. The average annual temperature in Europe has increased during the last three decades, while precipitation has decreased. Compared to the 5-year average, the European Union's (EU) severe drought in August is thought to have reduced maize, soybean, and sunflower yields by 16%, 15%, and 12%, respectively. Wheat exports are completely reduced when weather-related shocks or other occurrences cause disruptions in European wheat production (Schmidt and Felsche, 2024). According to these highlighted gaps, the aim of this research is an exploration of ways climate change negatively affects food production in Europe and the identification of climate variables that caused the adverse effects on food production, such as temperature and precipitation, drought, soil moisture, and many more, how they reduce the yield of different crops. The findings revealed a complex relationship between climate change and European food production.

Adverse effects of climate change on Food production in Europe

A long-term danger to food security, the amplitude of temperature and precipitation swings has grown, making conditions for cereal production unstable (Simionescu et al., 2019). Nonetheless, this occurrence makes it possible for northern European nations to improve crop conditions. According to Carozzi et al.'s (2022) study, a reduction in the length of the crop-growing cycle brought on by rising temperatures is expected to result in a considerable decline in grain yield between 2050 and 2099. This effect confirmed a regionally distributed impact of climate change, being more noticeable in the Mediterranean and more pessimistic climate scenarios (−7.7% for grasslands and −13% for croplands).

Adverse effects of Temperature and soil moisture extremes on Food Production

The continent of Europe is extremely sensitive to the rise in temperature brought on by climate change. Climate change forecasts throughout several European locations show consistent warming over the twenty-first century (Droulia and Charalampopoulos, 2021). Because of the growing season mean (or average), temperatures have already increased by 1.7 °C between 1950 and 2004, the current historical trend in this area (Droulia and Charalampopoulos, 2022). Soil temperature decreases, and plants unsuitable for climatic conditions and resistant to cold will be affected by roots and cause drying. As a result, a constantly increasing soil temperature will adversely affect plant life. It will decrease the efficiency (Bağdatlı and Ballı, 2020).

According to research by Schmidt and Felsche (2024), increased temperatures had detrimental effects on crop yields for maize in Italy, wheat in Germany, and wheat in Romania in June, May, and August, respectively. In France, however, there is a positive correlation between crop yields and a rise in October temperatures for barley. Based on their reports, they explained that variance drops by 7% and 3%, and extreme climate conditions have the most significant effects on barley in Poland and France. Dryer topsoil layers reduce crop yields for barley in Spain in June, maize in France in May, and barley in Poland in July. Additionally, excessive soil moisture negatively correlates with crop yields; for instance, in November, barley in Germany.

The world is being significantly impacted by global climate change, which also has a detrimental impact on the production of agricultural products. With the increasing global climate change, monitoring the product pattern and assessing regional temperatures is especially necessary (Bağdatlı et al., 2014). The effects of global warming caused by changes in the climate system of the highest peaks and ocean depths are felt throughout much of the world, from the equator to the poles. The polar ice caps are melting, the sea level is rising, and soil losses are experienced in coastal areas. Sea level due to glacier melting increased the temperature from 10 to 20 centimeters (Bağdatlı and Bellitürk, 2016a). Rising sea levels due to climate change can devastate forests, essential food sources in many locations (Afreen et al., 2022).

Adverse Effects of Drought on Food Production

Gradually decreasing rainfalls due to climate changes endanger the living habitat. As a precaution, precise solutions are needed to reduce carbon dioxide in the air, slow global warming, and eventually end it. In this way, the greenhouse effect and global warming can be prevented (Bağdatlı and Can, 2019).

According to the findings of Wang et al., (2024) a significant agricultural drought occurred during the 2022 extreme event, affecting steep-slope vineyards in Spain, northern and central Italy, northern Portugal, and southern France; olive groves in Spain and Italy; and maize and sunflower fields in the north of Spain, central Italy, southern France, and northern Romania. Terraced vineyards in the Alto Douro region of Portugal, the wine-producing region of Soave and Prosecco in Northern Italy, and the Priorate wine region in Spain are a few examples of the devastating effects of drought.

Additionally, there are some terraced olive trees, such as those in Sicily (Southern Italy) and the Malaga Region (Southern Spain). Fields that were treated using different techniques also experienced severe drought effects. For example, vineyards in Provence and the Languedoc districts of southern France are grown along the maximum slope; in central Italy (mostly the Apennines) and northern Spain, various herbaceous crops, such as sunflowers and maize, are grown. The drought negatively impacted crop yields. According to the yield reported by Baruth et al. (2022), the European Union has seen significant yield declines of −8.6%, −5.5%, and −9.6% for maize, sunflowers, and soybeans. While oil prices have increased by 80% in just two years, Spain, the world's largest producer of olive oil, lost over half of its yield from the previous olive season in 2022. Multiple research supports the prediction that the frequency of intense droughts will rise, especially in Europe (Hari et al., 2022; Straffelini and Tarolli, 2023; Ercin et al., 2021). For example, their climate model might affect 40 million hectares of agricultural landscapes in central Europe between 2050 and 2100, and drought episodes would rise sevenfold. In addition, it was projected that a 4 °C rise in Europe by 2100 may lead to a 10% decrease in output (Naumann et al., 2021). Compared to other agricultural regions, steep-slope agriculture is more vulnerable to the effects of drought brought on by climate change. For such systems to be sustainable, competent management is therefore essential (Wang et al., 2024).

Adverse Effects of Precipitation on Food Production

Europe has some of the most important and prestigious wine-making locations and wines, leading the world in wine production and viticultural areas. These are particularly common in the world's leading wine-producing nations (Tomasi et al., 2011), Italy, France, and Spain, where warming trends are unavoidable. For example, Bordeaux, France, has seen an annual mean temperature increase of 2.1 °C, and Veneto, Italy, has seen a growing season mean temperature rise of 2.3 °C over the past 50 years (Aurand, 2017 ; Tomasi et al., 2011). A significant atmospheric factor affecting grape development is precipitation and its temporal distribution, which significantly affects soil moisture and the grapevine's water potential, particularly in non-irrigated vineyards (Schoener et al., 2020 ; Huang et al., 2016 ; Rodrigues et al., 2012). Bud break, stalk and inflorescence development, and the dry, constant air conditions from blooming to berry ripening all need high soil moisture. Excessive vigor caused by abundant soil moisture throughout the growing season may encourage widely covered canopies. This could hurt the vine's performance, including decreased bud break, delayed maturity, increased berry weight, and deteriorated fruit and wine quality. Excessive humidity overstimulates vegetation growth, creating denser canopies and increasing the risk of plant epidemics (e.g., leaf and inflorescence diseases), which has detrimental effects on productivity. Excessive precipitation causes drowned vines to develop (Droulia et al., 2022).

Adverse Effects of Land Usage on Food Production

The usage of land is the first effect of climate change. Changes in land use brought on by natural disasters, human activity, and the climate mean that certain crops may no longer be able to be grown in some areas because of heat or drought (Verweij et al., 2018). At the same time, new locations may do so because of the warmer temperatures there.

Furthermore, structural changes like floods that destroy or wash away existing land could be brought on by climate change (Swain et al., 2020). Also, for reasons other than climate change, such as deforestation or converting productive land for urban expansion, new agricultural land may be acquired, or current land may be lost later in life (Verweij et al., 2018).

Food safety Hazards

Food safety hazards occur as a result of climate change; mycotoxin-based food safety risks are one major category that climate change is predicted to affect certain fungal species that create poisons known as mycotoxins after infecting crops (Zingales et al., 2022). Mycotoxins are undesirable in feed and food since they harm people and animals (da Rocha et al., 2014). Climate change is predicted to significantly affect crop mycotoxin contamination since weather plays a significant role in both fungal infection and mycotoxin generation. One of the most harmful classes of mycotoxins is aflatoxins, which are immunotoxin, genotoxic, and carcinogenic. Aflatoxins can seriously affect humans and agricultural animals (Damiano et al., 2022). *Aspergillus* species, *especially A. flavus*, create aflatoxins, which infect *Zea mays* (maize) and other crops. Thermotolerant fungi that have acclimated to warmer climates are Aspergillus species. Therefore, crops grown in tropical and subtropical regions, such as maize, rice, and nuts, are the primary source of aflatoxins. However, several studies have already indicated that aflatoxins in maize will also become a significant food safety problem in Europe due to climate change. The primary causes of aflatoxin formation are weather extremes like droughts and high temperatures (Focker et al., 2023). Today, among other Southern European nations, Italy, Croatia, Serbia, and Hungary have reported significant levels of *A. flavus* and aflatoxins. High levels of mold development and aflatoxin formation in maize were caused by hot, dry weather in Serbia in 2012. Dairy calves were fed this highly contaminated corn, which resulted in high aflatoxin levels in Serbian milk in 2013 and 2014 and had a significant negative economic impact (Focker et al., 2023; Popovic et al., 2017). The distribution of *A. flavus* spores is known to be influenced by precipitation and relative humidity. On rainy days or when the relative humidity is greater than 80%, spores do not disperse (Battilani et al., 2013). Although it is frequently not a limiting element, water activity affects sporulation. Drought is a significant factor rather than precipitation or relative humidity. Crops are particularly vulnerable to fungal infestations during drought (Chauhan et al., 2015).

Adverse Effects of climate change on Aquaculture and Fisheries production

European seas contribute to over one-eighth of global fisheries catches, making the EU the second-largest trader of fisheries and aquaculture products after China in 2019. European seas, mainly enclosed or semi-enclosed basins such as the North, Mediterranean, and Norwegian, are experiencing rapid warming (Predragovic et al., 2023). Aquaculture and marine ecosystems are expected to be threatened by climate change. Aquaculture species, ideal production ranges, and localization patterns may all undergo substantial changes due to rising sea temperatures.

Seasonal and temperature changes may impact breeding and migration. Climate change regulates several aquatic activities that impact the lifespan of organisms. Higher water temperatures, for instance, may shorten salmon life spans and make diseases more likely (Ogunkalu, 2021). The decrease over time of the changes in the water's surface is noticeable. This also shows the effect of disorder in the vaporization and current precipitation regime in the water sources dependent on climate change (Albut et al., 2018).

This alteration is expected to contribute to a further drop in salmon populations when paired with climate influences. The distribution of aquatic life, especially seaweeds, will change as sea temperatures rise, and farmed organisms will generally move northward. Aquatic animals that are used to living in cold water may be at risk from increased summer sea surface temperatures. The production of aquaculture species may result in decline, and Southern Norway may lose its suitability for species like salmon, with socioeconomic repercussions (Bağdatli et al., 2023; Hermansen and Heen, 2012 ; Stévant et al., 2017). Climate change has become the focus of constant attention on living things, and civilizations consider the climatic parameters determined by their lifestyles. Climate increases or decreases in changes affect living things negatively. A decrease in productivity, especially in agricultural production, causes (İstanbulluoğlu et al., 2013).

Temperature increases and decreases negatively affect the lives of living things. It will be difficult to find clean water in the future as temperature increases increase the evaporation level. Increasing or falling temperatures will cause climate change (Bağdatlı and Can, 2020).

CONCLUSION

The demand for agriculture to maintain global food and nutritional security has increased due to population growth, and climate change is worsening. Numerous studies indicate that climate change will reduce agricultural productivity in the upcoming years in Europe, even though there are uncertainties surrounding the future climate situation and its potential effects. A pest infestation, soil fertility, irrigation supplies, physiology, and plant metabolic activities were severely impeded by the three main determinants of climate: temperature, precipitation, and greenhouse gasses. The resulting changes in temperature and rainfall can alter cereal yields in European Union countries. With the increasing global climate change, monitoring the product pattern and assessing regional temperatures is especially necessary.

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Irradiation Applications in Food Products

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Abstract

To prevent hunger and malnutrition in the world, increasing food production alone is not enough. However, food safety and quality must also be ensured in the preservation of the produced food. For this purpose, in addition to the use of traditional methods, innovative methods such as irradiation have been developed and put into practice. Food irradiation is a technology used to reduce pathogens and food-borne diseases by giving a certain amount of energy to packaged or bulk foods, and to improve food safety by inactivating microorganisms that may cause food spoilage. Today, approximately 200 types of foods are irradiated in many countries using irradiation technology. Some of these foods are fruits and vegetables, meat and meat products, eggs, spices and aromatic plants, nuts and oilseeds. This article aims to provide information about irradiation, to mention irradiation applications in some foods (irradiation of fruits and vegetables, meat and meat products and spices), and to mention consumers' perspectives on irradiated food.

Keywords: Food Irradiation, Food Safety, Food Processing

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INTRODUCTION

Hunger and malnutrition are among the most important problems encountered in the world (UN News, 2017). In order to overcome the hunger problem, it is not enough to increase food production alone, in addition to this, preservation methods should be applied in the quality and reliability of food. It is very difficult to transport and protect products without any loss in the products during food preservation. For this reason, innovative methods are also used in addition to traditional methods (Halkman et al., 2010).

The history of food irradiation dates back to the discovery of X-rays by Roentgen in 1895 and the discovery of radioactivity by Becquerel in 1896 (Diehl, 2002). Currently, irradiation is applied to one or more foods in more than 60 countries in the world; among these countries, China, the USA and Ukraine have the largest share of irradiated foods, and China is one of the leading countries in its trade. Two gamma irradiation facilities have been established in Turkey, the first of which was established in Sarayköy/Ankara in 1992 and the second in Çerkezköy/Tekirdağ, the first private sector commercial facility established in 1995 (Sarıbay, 2017).

Food irradiation technology is the application used to improve food safety with a certain energy, namely ionized energy, in packaged or bulk foods (Arvanitoyannis, 2011; Sarıbay, 2017). In this context, 3 types of irradiations are used in food preservation: gamma rays, X-rays and accelerated electron beams (Olson, 1998; Ceylan and Özoğul, 2020). Among these, gamma rays are the most frequently used in industry (WHO, 1994). According to the Food and Agriculture Organization (FAO), World Health Organization (WHO), Codex Commission (CAC) and International Atomic Energy Agency (IAEA), which have worked together on the quality and safety of many irradiated foods, it has been concluded that the application of irradiation technology with one or more methods is a technology that extends the shelf life of foods and also provides microbial safety (IAEA, 2009). Every product using irradiation technology must have the 'radura' symbol on its packaging to inform the consumer (Figure 1). This article includes a diversity of the history of technology, its assessment and applications in various food groups, and consumer perception.

Figure 1. Radura symbol

PURPOSES, ADVANTAGES and DISADVANTAGES of FOOD IRRADIATION

Food irradiation is not only used to reduce disease-causing microorganisms (pathogens) and foodborne illnesses, to eliminate microorganisms that will cause spoilage, to minimize food spoilage, but it can also be used in foodstuffs to reduce product losses during sprouting, germination and ripening, and to reduce the contact of organisms that are harmful to plants or plant-derived products with foodstuffs (Halkman et al., 2010).

Food irradiation has both positive and negative aspects. Its benefits are that food products remain more natural due to not being exposed to heat, that it has a comprehensive effect on microorganisms and insects that cause food-based harvests, that it can be applied to packaging and therefore protects people from epidemics caused by food, and that it also has a positive effect on the rate of food-borne diseases as a result of studies (Hoefer et al., 2006; Nayga et al., 2004). In addition to this, it does not leave any chemical traces in food products and reduces the use of chemical substances in many food sectors (WHO, 2005). It is also used to prevent pests in some tropical or semi-tropical vegetables and fruits from spreading to different regions with export. It slows down ripening and rotting in foods, ensures that the product maintains its freshness for a longer period, and as a result, the shelf life of the product is extended.

In terms of the negative aspects that need to be improved, the consumer's perspective on irradiated food is one of the obstacles to the widespread use of this technology. However, some studies have yielded some unpleasant results in the physical properties of foods (taste, smell and texture). At the same time, radiolytic products can be released by irradiation. The most important radiolytic product of these is 2-alkylcyclobutanone. This is determined by the standards published by the European Standardization Board in the determination of irradiated foods (EN, 1785).

IRRADIATION APPLICATIONS in FOODS

The essence of the successful implementation of irradiation in food products is based on the inhibition of DNA synthesis during cell division. Inactivation of microorganisms by irradiation is the result of DNA damage (Halkman and Kozat 2005; Anonymous, 2005; Dickson, 2001; Farkas, 1997).

Although irradiation is an effective method used to preserve fresh and perishable foods because it is a physical process that leaves no chemical residue (traces), it is not possible to use it on every food (Lagunas-Solar, 1995). For example, rancidity in fatty food products and bad odor and taste formation in high-protein food products narrow down the area of use of irradiation. Currently, approximately 200 types of foods are irradiated using irradiation technology in many countries. (Farkas and Mohacsi-Farkas, 2011; Cleland and Stichelbaut, 2013; Mitchell, 1994; Lee et al., 2004). Some of the foods subjected to irradiation are fruits and vegetables, meat and meat products, eggs, spices and aromatic herbs, nuts and oilseeds (Yılmaz and Ülger, 2016; Olson, 1998); the irradiation of fruits and vegetables, meat and meat products and finally spices are explained below.

Irradıatıon of Fruıts and Vegetables

Losses occur in products due to different reasons in the stages from production of fruits and vegetables to reaching the consumer. Although various techniques such as early harvesting, chemical use, storage in cold atmosphere and packaging are used in production in order to reduce these losses, the effect of water and microbial activities on fruits and vegetables on losses is high. For this reason, in addition to food preservation methods, the use of irradiation methods is also important in minimizing losses (Dinçer and Topuz, 2006). As a result of irradiation, sprouting of fresh fruits and vegetables is prevented, ripening is controlled, insects and pests are inactivated and finally mold, yeast and bacteria are inhibited (Farkas, 2006). Chemical applications are mostly used to ensure the microbial safety of fresh fruits and vegetables, and the chemical traces left by these in foods are a major negativity in their use. Microbial safety can be achieved without leaving any chemical traces in fresh vegetables and fruits by irradiation (Başbayraktar and Güçlü, 2009).

Many studies have been conducted to extend the shelf life of fresh fruits and vegetables. (Farkas, 1990; Lacroix et al., 1991). A study conducted by the Canadian Irradiation Center on citrus fruits showed that washing with warm water and waxing processes to extend the shelf life of foods caused losses in fruits during storage, and it was stated that there was a loss of less than 11% in tangerines irradiated with 0.3 kGy and stored at 3°C after 8 weeks (Abdellaoui et al., 1995).

In a study where low doses (0.25-1 kGy) of γ-rays were applied to packaged Basmati rice to prevent infestation, extreme infestation was detected in unirradiated rice after 30 days of storage at room temperature, while it was not detected in irradiated rice even at a dose of 0.25 kGy (Sudha Rao et al., 2000).

In a study for the inactivation of Hepatitis A virus (HAV), gamma irradiation doses ranging from 1 to 10 kGy were applied to inoculate green lettuce and strawberries at room temperature, and as a result of data analysis with the linear model, it was determined that gamma irradiation doses between 2.7 and 3 kGy were required to achieve a 90% reduction in the HAV population in fruits and vegetables (Bidawid et al., 2000).

In the study conducted to determine the effect of irradiation technology on the quality of lightly processed carrots, carrots were peeled, sliced and packed in polyethylene packaging material. Following irradiation and during two weeks of storage, no coliform or E. coli was detected in any sample (irradiated or control). As a result, irradiation at 2 kGy completely reduced the number of fungi and bacteria (Chaudry et al., 2004).

As a result of the investigation of Listeria monocytogenes inactivation in broccoli, cabbage, tomato and mung bean seeds inoculated in the laboratory; it was determined that irradiation at 1 kGy caused a decrease of 4.88 log cfu/g in broccoli seeds and 4.57 log cfu/g in bean seeds, and these rates caused a decrease of approximately 5.25 log cfu/g in cabbage and 4.14 log cfu/g in tomatoes irradiated at similar doses. As a result, it was stated that irradiation applied at low doses could be an effective method for the inactivation of L. monocytogenes in fresh and fresh-cut products (Bari et al., 2005).

It is known that the use of irradiation technology in fresh fruits and vegetables not only neutralizes microorganisms that cause spoilage, but also has a positive effect on the shelf life of the product. Although many different fruits and vegetables are tolerant of low-dose applications, the biggest obstacle to the use of food irradiation in fruits and vegetables is the softening that occurs in the products (Fan et al., 2003a; Fan et al., 2003b). "Low" irradiation doses of up to 1 kGy are indicated as suitable for controlling insects in cereals, preventing sprouting in white potatoes and preventing rotting in fruit and vegetables (Webb and Penner, 2000).

Irradiation of Meat and Meat Products

Meats are very sensitive to oxidative deterioration caused by the oxidation of polyunsaturated fatty acids in their structure (Giroux and Lacroix, 1998). With irradiation, the abundant water in meat is ionized and free radicals are formed. These free radicals cause lipid and protein deterioration, which creates an undesirable taste in meats (Merritt et al., 1978; Giroux and Lacroix, 1998). Since polyunsaturated fatty acids are oxidized rapidly, precautions must be taken during irradiation (Merritt et al., 1978). Today, in poultry meat, the only physical method that can make contaminated poultry safe, in addition to heat treatment, is irradiation. 11 countries have recognized the value of irradiation technology in the safety of poultry products and have approved the use of irradiation in this area (Molins et al., 2001).

It has been determined that doses lower than 10 kGy are used to control the growth of pathogenic and spoilage bacteria (*L. monocytogenes, S. typhimurium, E. coli* O157:H7 and *Y. enterocolitica*) in meat and meat products (Thayer and Boyd, 2001; Mermelstein, 2000; Monk et al., 1995). It has been determined that most enteric pathogens (*Campylobacter jejuni, Escherichia coli O157:H7, Staphylococcus aureus, Salmonella spp., Listeria monocytogenes and Aeromonas hydrophila*) can be significantly reduced or inactivated with low-dose (< 3 kGy) irradiation applications in poultry meat. Only enteric viruses and endospores of the Clostridium and Bacillus genera show serious resistance to irradiation, and these are affected to some extent (Thayer, 1995). Low doses of irradiation play an active role in inactivating Salmonella species as well as keeping food fresh for a long time. In a study conducted in this context, irradiation of fresh chicken carcasses, parts or boned chicken meat at 2.5 kGy is generally appropriate in preventing inactivation with natural Salmonella found at very low levels (1 to 30 cells/100 g). In frozen chicken, doses higher than 2.5 kGy are needed to ensure inactivation of Salmonella spp. (Singh, 1992). There are studies that conclude that the irradiation applications recommended for inactivating *Salmonella spp*. and *Listeria monocytogenes* from poultry carcasses are also sufficient for Campylobacter species (Patterson, 1995).

Although irradiation is a method that has been used successfully to reduce the number of *E. coli O157:H7* in red meat and poultry, radiation sensitivity depends on different factors. After 1 kGy irradiation, a decrease of 3-4 logarithmic units was found in the initial number of *E. coli.* D10 = 0.27 kGy was determined in meat medium and D10 = 0.47 kGy in turkey meat (Mayer, 1993).

Various studies have determined that *E. coli O157:H7* is not resistant to irradiation and that irradiation will provide significant hygiene protection in food products, especially meat products (Halkman et al., 2001).

In a study evaluating the sensory properties (flavor and liking) of meatballs prepared from beef and irradiated at a dose of 1.5 kGy, these properties were examined, and it was concluded that there was no difference in total liking, hardness, flavor and textural liking between irradiated and non-irradiated samples, only irradiated meatballs were juicier and had a redder color (Vickers and Wang, 2002).

Fresh fish have a short shelf life because they are sensitive to microorganisms that may cause spoilage in their structure (ICGFI, 1998). Gram-negative bacteria, which are the main cause of spoilage in marine and freshwater fish, are more sensitive to irradiation applications than Gram-positive bacteria. In other words, by applying low irradiation doses such as 1-3 kGy, the initial load of microorganisms that may cause possible spoilage can be reduced by 1-3 logarithm units, thus increasing the storage period of fresh fish. The dose level to be used in irradiation to increase the storage period is determined according to the amount that will not endanger health for each species and to have sensory properties acceptable to the buyer (Grodner and Andrews, 1991). Food irradiation can change the quality of meat products as well as their color, lipid oxidation and microbial properties (Ham et al., 2017). Excessive dose application during the irradiation process can cause undesirable changes, especially in meat products, due to increased lipid peroxidation in foods and negatively affecting the shelf life of foods (Kima et al., 2002; Lung et al., 2015).

Spice Irradiation

Spices, which are frequently used in the world, are contaminated with bacteria, yeasts and molds when they encounter unhygienic conditions during harvest, growing conditions and various stages such as drying, and their microbial loads also increase (Sagoo et al., 2009; Roberts, 2016). While the low water content and ratio of spices cause their microbiological activity to be low, they can cause microbiological contamination when they are together with foods with high water content and activity (Schweiggert et al., 2007).

Spices and aromatic plants are sterilized with steam, ethylene oxide or irradiation before they reach humans. Their use is limited due to the losses in volatile fatty acids in steam sterilization and the toxic effects of ethylene oxide sterilization. Gamma irradiation is a method that is successfully applied in spices because it does not change the aroma quality and prevents microbial contamination (Farkas, 1988). In the last five years, the irradiation of spices and condiments has increased, from 2.5% to 22.5%. According to January 2000 data, 95 million pounds of the total 97 million pounds of food irradiated annually in the USA were determined to be spices (Abbas, 2002; Piggott and Othman,1993).

It is the most common application used to ensure the hygiene and health conditions of spices; international organizations and institutions such as FDA and WHO also approve irradiation of spices (FDA, 2016).

It is mentioned that irradiation application in spices is a very effective and reliable type of sterilization because it causes a significant decrease in the number of bacteria (Hayashi et al., 1994; Szabad and Kiss, 1979; Sirnik and Jamsek, 1981). For example, it has been determined that 10 kGy dose of irradiation in pre-packaged spices with a high microorganism load eliminates microorganisms without any loss of quality, and that 5 kGy dose is sufficient to eliminate molds (Abbas, 2002).

CONSUMER and IRRADIATED FOOD

In order for an application to be commercially implemented, it must be adopted by the consumer. Consumers' approach to irradiation technologies and the products they are applied to is mostly negative due to fear, incorrect and insufficient information about the application. In a study conducted in the USA, it was determined that 82% of consumers were unaware of irradiation application, while 72% were aware. In the study, 30% of consumers were of the opinion that foods were radioactive (Resurrection, et al., 1995).

It has been determined that information and educational activities about irradiation carried out by researchers are effective in consumers' perspectives on food (Fox, 2002; (Oliveira and Sebato, 2002). Consumers' perspectives on food safety vary depending on cultural and demographic factors such as gender, age, marital status, income and education level, country's level of development, etc. (Wilcock et al., 2004).

In a study of consumer attitudes toward food irradiation in São Paulo, Brazil, three focus groups were conducted with 30 consumers. Participants were served both irradiated and non-irradiated food samples during the sessions and their reactions were observed. The results were similar between the groups, with almost no perceptible differences between the irradiated and non-irradiated samples.

When consumers were provided with information about the benefits of irradiation to food and human health, many people remained skeptical about the safety of technology (Behrens et al., 2009). In another study, a consumer panel of 50 people was recruited to evaluate the sensory properties and consumer acceptance of electron beam irradiated ready-to-eat meats. The acceptability of irradiated foods was higher than that of non-irradiated ones. Approximately 76% preferred to purchase irradiated pork and 68% preferred to purchase irradiated poultry to minimize the possibility of contracting Trichinella and Salmonellae, respectively (Johnson et al. 2004).

As a result of the joint studies conducted by FAO, IAEA, WHO and CAC on the quality and safety of food using various irradiation applications, it has been determined that irradiation technology, whether used alone or in addition to another method, is a technology that provides microbial safety in food and is used in food preservation (IAEA, 2009).

CONCLUSION

Food irradiation is a technology that has found application in different sectors of food due to its many advantages and has developed over time. Although irradiation applications vary depending on the type of products to be irradiated, studies on it are still ongoing today.

In recent years, with the understanding of the value of irradiation, consumer awareness efforts have begun to increase. In this context, more studies are needed on the subject, and awareness of food irradiation should be created by supporting the studies by various institutions and organizations and presenting them to consumers.

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Impact of Pistacia Terebinthus on The Antioxidant Activity and Total Phenolics of Ice Cream Depending on Roasting Conditions and Incorporation Time

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Abstract

Pistacia terebinthus (terebinth) is in the same family with P. vera and contains considerable amounts of bioactive compounds with antioxidant, anti-inflammatory, hypolipidemic and neuroprotective activities. Although pistachio (P. vera) is a common ingredient used in ice cream, P. terebinthus consumption is limited to being a snack food or coffee-like drink. In this study P. terebinthus examined for its antioxidant activity under different conditions and it is added to the ice cream to increase its antioxidant activity while providing a new flavor option. P. terebinthus was added to the ice-cream after roasting at different temperatures (A: 0, B: 100, C: 125 and D: 140°C for 20 min.). Raw and roasted P. terebinthus seeds were milled, hard shells were removed and added to the ice-cream mix before pasteurization of the mix. Chemical composition, physical properties and sensory results of ice-creams (A, B, C and D) were compared to the control (K) that doesn't contain P. terebinthus. Adding P. terebinthus to ice-cream reduced its pH, lengthened its melting time, however didn't affect its viscosity as compared to K. Change in the antioxidant activity (AA) and total phenolic content (TPC) of P. terebinthus due to any possible interactions with milk proteins and sugar when heating the ice-cream mix was also examined by comparing the control P. terebinthus solution with milk solutions (9% milk powder, 10% sugar) where P. terebinthus is added before and after heating milk solutions (80°C for 1 min.). Heat treatment of milk solution together with P. terebinthus reduced its AA. Roasting increased the TPC and AA of P. terebinthus. Highest AA was observed at ice-cream C.

Keywords: Functional ice-cream, Pistacia terebinthus, Antioxidant activity, Total phenolics, Heat treatment

Research article
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INTRODUCTION

P. terebinthus L. (turpentine tree, terebinth) is in the same family with P. vera and grows in the Mediterranean region and some parts of Asia. P. terebinthus fruits possess many biological activities due to being rich in flavonoids and other phenolic compounds. Although P. vera is a common flavor used in ice cream, P. terebinthus consumption is very limited and unknown by most people. However, it drawn the interest of researchers due to its AA (Topçu et al., 2007), anti-inflammatory properties and high oil content (Matthäus and Özcan, 2006). An investigation found strong anticholinesterase activity in P. terebinthus extracts (Hacıbekiroğlu et al., 2015). Bakirel et al. (2003) showed that P. terebinthus extracts of dried fruits have hypolipidemic effect on animal tests. Orhan et al. (2012) claimed that roasted P. terebinthus could be neuroprotective due to its BChE inhibitory effects and AA. Impact of roasting on phenolic content of P. terebinthus oil was studied and an increase in TPC and AA was reported (Durmaz and Gökmen, 2011; Dalgıç et al., 2011).

Although ice cream is an important nutrient with its protein and fat content, it is not rich in antioxidants and phenolic substances alone. On the other hand, ice cream is a good carrier for many nutraceuticals, and with this feature it has been used in the production of functional foods in many studies (Goraya and Bajwa, 2015). Enriching ice cream with grape, pomegranate and sesame powder and oils (Akça and Akpınar, 2021), black carrot concentrate (Pandey et al., 2021), herbal tea (Karaman and Kayacier, 2012) blueberries (Pehlivanoğlu et al., 2024), propolis (Mehmetoğlu and Tarakçı, 2023) and pistachio shell (Ghandehari Yazdi et al., 2020) are some of these studies. Adding P. terebinthus to ice cream would produce a functional food with health benefits and would provide a new way for widespread consumption of P. terebinthus. There has been a considerable interest in the incorporation of polyphenols to dairy products to enrich their nutritional and functional properties. However, phenolic compounds can strongly interact with milk proteins, causing functional and structural changes (Jakobek, 2015); and these interactions could reduce the AA and bioavailability of the phenolics (Arts et al., 2001; Arts et al., 2002; Serafini et al., 2003; Stojadinovic et al., 2013). At what stage of the process they are added to the milk system is also important since processing conditions can influence the interactions of polyphenols. Heat treatment of the ice cream mix is one of the main processes involved in ice cream making. It was reported that AA of certain polyphenol–milk protein complexes negatively affected by heat treatment (Kılıç Bayraktar et al., 2019). Therefore, we also wanted to examine the change in the AA by the stage of adding P. terebinthus before and after heat treatment of milk solutions; and we also evaluated the masking effect of ice cream on P. terebinthus.

MATERIAL and METHOD

Materials

Fresh fruits of P. terebinthus were purchased at local markets in Şanlıurfa, Turkey. Non-fat milk powder (96% total solids), cream (35% fat) (Pınar Dairy, Turkey), lecithin (Sosa Ingredients, S.L. Ctra de Granera, Spain) as emulsifier and a blend of stabilizers that contain equal amounts of Karragenan (E 407), Guar gum (E 412), Sodium alginat (E 401), Xanthan gum (E 415) and dextrose (KATPA, Katkı Maddeleri Gıda Sanayii ve Ticaret Ltd. Şti., Türkiye) was used for ice-cream making.

Preparation and heat treatment of Pistacia terebinthus extracts

Damaged fruits and foreign matters were discarded and layered in aluminum trays as a single layer for heat treatment at temperatures selected by preliminary trials. One group kept untreated (A), and other groups were roasted in oven that is set to 100 (B), 125 (C) and 140°C (D) for 40 min. After cooling down to room temperature, they were milled using a laboratory mill in such a size that the shells do not pass under the sieve. Obtained P. terebinthus paste was sieved by adding water (1:6) to be able to remove the hard-shell pieces. These P. terebinthus extracts were prepared the day before ice-cream production and kept at 4°C.

Ice cream manufacture

Mix (11% non-fat solids (NFS), 5% fat, 18% sugar, 0.8% emulsifier and 0.2% stabilizer) was prepared and 5% P. terebinthus roasted at 0°C (A), 100°C (B), 125°C (C) and 140°C (D) was added. One batch from each production was set as control (K) and no extract was added. All ice cream mixes were heat treated at 80°C for 1 min, stirred well with a blender while still hot and aged for 24h at 4°C. A vertical freezing machine with 6 kg capacity (Uğur, Nazilli, Turkey) was used for freezing the mix and the ice cream was packed in 200 mL cups and stored at −18˚C. All trials were duplicated, and the analyses were carried out at least in duplicate.

Determining the impact of P. terebinthus incorporation stage

AA and TPC were compared between control (5% P. terebinthus solution) and milk solutions (9% milk powder, 10% sugar) where 5% P. terebinthus is added before and after pasteurizing the milk solutions at 80°C for 1 min. Raw and roasted (125°C) P. terebinthus extracts were used. Sample codes for controls; A0: Raw P. terebinthus, C0: Roasted (125°C 40 min) P. terebinthus, for milk solutions; A1: raw P. terebinthus added before pasteurizing, A2: raw P. terebinthus added after pasteurizing, C1: roasted P. terebinthus added before pasteurizing, C2: roasted P. terebinthus added after pasteurizing.

Masking of total antioxidant activity

Masking of total AA calculated as percent difference between sum of AA of P. terebinthus + K and AA of ice creams with P. terebinthus (Stojadinovic et al., 2013).

Proximate analysis of ice cream samples

Fat (IDF, 1991), total solids, ash, pH and titratable acidity (Bradley et al., 1992) were determined 1 week after the production.

ABTS assay

ABTS·+ radical scavenging activity was measured at 1 week. Briefly, 7 mM ABTS stock solution was reacted with 2.45 mM $K_2S_2O_8$ and kept in the dark at room temperature for 12–16 h. Then it was diluted to an absorbance of 0.70 ± 0.03 at 734 nm by adding 5 mM phosphate buffered saline (pH 7.4). For the photometric assay, 2.980 ml of the ABTS·+ solution was added to ethanol extracts of samples and after waiting 6 min, their absorbance measured at 734 nm (Re et al., 1999). Calibration was done with trolox stock solution. Inhibition of ABTS·+ was calculated by the following equation:

$ABTS^{\cdot+}$ Inhibition (%) = [(Ac-As)/Ac x 100]
Ac; Absorbance of the blank, As; Absorbance of the sample

DPPH assay

DPPH radical scavenging activity was analyzed at 1 week. Briefly, 2.9 ml of 0.1 mM DPPH was added to ethanol extracts of samples and absorbance was detected at 517nm after 30 min. DPPH inhibition capacity of the samples were calculated by the following equation (Blois, 1958):

DPPH Inhibition (%)= [(Ac-As)/Ac x 100]
Ac; Absorbance of the blank, As; Absorbance of the sample

Determination of Total Phenolic Contents

The amount of phenolic compounds in ethanol extracts of samples were determined by the Folin–Ciocalteu colorimetric method described by Slinkard and Singleton (1977) with some modifications. Sample extract (0.03 mL) was mixed with 2.37 mL distilled water and 0.15 mL Folin–Ciocalteu's reagent. After waiting for 8 min. 0.45 mL Na_2CO_3 was added and kept 30 min. at room temperature for reading. The absorbance was measured at 750 nm and total phenolic concentrations (mg/kg) were estimated using gallic acid standard curve.

Physical analysis of ice cream samples

The apparent viscosity of the samples were determined according to Dervisoglu et al. (2004) using ice cream samples equilibrated to 4°C for 12h prior to the test. A Brookfield Viscometer (Model DV-II; Bookfield Engineering Laboratories, Inc., Stoughton, MA, USA) with spindle no 5 was used.

The overrun of the ice cream samples was estimated using the following equation (Jimenez-Florez et al., 1993).

Overrun = (Weight of unit mix - weight of equal volume of ice cream) / (Weight of equal volume of ice cream) * 100

Melting behavior expressed as the first dripping time and melting rate, was evaluated by weighing 80 ± 5 g ice cream sample on a 0.2 cm wire mesh screen that was left to melt at room temperature (24 ± 2°C) (Abd El-Rahman et al., 1997; Cotrell et al., 1979). The time it takes to see the first drop of ice cream was measured as first dripping time. The melted ice cream weight was recorded at 30th, 45th, 60th and the 90th min. Time of complete melting was also recorded.

Sensory analysis

Sensory analysis was conducted by ten untrained panelists involving the staff from the Harran University Department of Food Engineering. Panelists were familiar with dairy products and were checked based on sensory perception and reliability. A 10-point hedonic scale was used to examine color and appearance, firmness, smoothness, gumminess, meltdown, iciness, flavor and taste and general acceptability (1=strongly unacceptable, 10 = very good) as described by Aime et al. (2001).

Each panelist received 5 samples of ice cream to taste and to evaluate at each serving. Panelists were also requested to drink water between the samples in order to maintain discretion. All physical, chemical and sensory analyses were carried out 1 week after the production.

Statistical analysis

Statistical analysis was performed by SPSS version 16 (SPSS Inc., Chicago, IL). Analysis of variance (ANOVA) was done to establish statistical differences between the chemical and physical properties of the samples. Statistically different groups were determined by the Duncan multiple comparison test ($p<0.05$).

RESULTS and DISCUSSION

Composition and physical properties of ice creams

Control ice cream (K) had 36.2±0.72% total solids, 3.55±0.21% fat, 1.1±0.03% ash, 0.25±0.03% titration acidity and a pH value of 6.9±0.03. No significant difference ($p>0.05$) was observed between ice cream samples with 5% P. terebinthus, having 38.69±0.19% total solids, 5.18±0.13% fat, 1.19±0.00% ash, 6.75±0.01 pH and 0.31±0.00% acidity in average. Adding P. terebinthus increased the total solids, fat and ash content as expected, and due to their higher acidity, they increased the acidity of the ice creams as well.

Table 1. Physical properties of the ice cream samples

Measurement		K	A	B	C	D
Viscosity (cP)		12021±218 [a]	12258±7 [a]	11376±0 [a]	12862±891 [a]	12795±1050 [a]
Overrun (%)		29.37±2.95 [a]	28.30±1.77 [ab]	24.82±0.11 [bc]	28.70±0.60 [ab]	22.18±0.52 [c]
First dripping time (s)		709±0.00 [a]	690±4.24 [c]	683±0.00 [d]	698±1.41 [b]	710±0.71 [a]
Melting rate (%)	15th min	0	0	1.69±2.38	0	0
	30th min	17.64±7.17 [a]	0.82±1.15 [c]	11.04±3.24 [b]	1.72±1.83 [c]	2.47±2.09 [c]
	45th min	70.22±7.98 [a]	23.79±7.80 [d]	67.55±7.34 [a]	46.85±7.02 [b]	32.30±0.16 [c]
	60th min	90.31±0.13 [a]	80.03±7.45 [b]	83.21±850 [ab]	77.64±5.76 [b]	86.05±5.68 [ab]

[a,b,c] Values with different superscript letter in the same column are significantly different ($P<0.05$)
*K: Control with no *P. terebinthus*, A: Raw *P. terebinthus*, B: 100°C roasted *P. terebinthus*, C: 125°C roasted *P.terebinthus*, D: 140°C roasted *P. terebinthus*

Physical properties of the ice creams are given in Table 1. No significant difference was observed between the apparent viscosities of the ice cream samples ($p>0.05$). Slight differences were observed between overrun values, with K having a little higher overrun, which could be due to the hindrance of the overrun by P. terebinthus. Most of the studies that involve adding fruits or nuts reported a decrease in overrun (Ghandehari et al., 2020, El-Samahy et al., 2009, Hwang et al., 2009). While first dripping time was longer than the others for ice cream K, its melting rate was faster. Previous studies showed that adding ingredients such as polysaccharides and fibers with high water holding capacity would reduce the melting rate of the ice cream (Hwang et al, 2009, Karaman et al., 2014; Erkaya et al. 2012). Fiber content of the P. terebinthus could have reduced the melting rate. It appears that roasting the P. terebinthus influenced the melting rates.

While raw P. terebinthus reduced the melting dramatically, the fastest melt had occurred at milder temperatures within the roasted P. terebinthus. This could be due to a decrease in the water binding capacity of the components in P. terebinthus caused by heat treatment.

Antioxidant activity and total phenolics content of ice creams

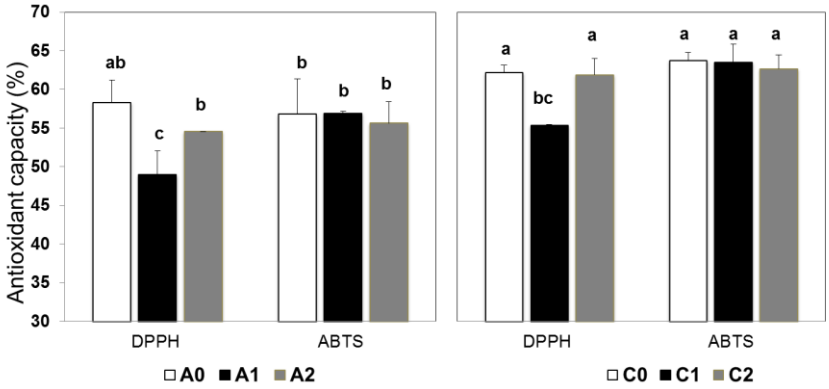
Changes in the antioxidant capacity and TPC of the ice cream samples are given in Table 2. Roasting the P. terebinthus significantly influenced the AA and TPC of ice creams ($P<0.05$). Ice creams with raw P. terebinthus had the lowest TPC and AA. There was a proportional increase in both AA and TPC with the increase in roasting temperature until 125°C. Above that temperature it was either stable or a decrease was observed (ABTS inhibition). It is previously reported that, roasting induce several changes to phenolic compounds of nuts and seeds. While some phenolics break down, some other new phenolic compounds are formed with heat treatment (Durmaz and Gökmen, 2011). Certain Maillard reaction products formed by heat treatment also have AA (Lertittikul, et al., 2007). In a previous study, roasting increased the TPC, AA and oxidative stability of P. terebinthus oil, while the level of tocopherols, lutein and β-carotene was decreased (Durmaz and Gökmen, 2011).Dalgıç et al. (2011) also reported an increase in TPC and AA of P. terebinthus oil together with an increase in total carotenoids and most tocopherols.

Table 2. Changes in antioxidant capacity and total phenolic content of the ice cream samples

	K	A	B	C	D
DPPH (%)	1.72 ± 1.49^{a}	53.89 ± 0.35^{b}	55.71 ± 0.35^{bc}	58.49 ± 0.96^{d}	56.46 ± 0.97^{cd}
ABTS (%)	17.00 ± 1.63^{a}	50.59 ± 0.93^{b}	53.02 ± 0.77^{c}	57.93 ± 0.19^{e}	55.72 ± 0.19^{d}
Total Phenolics (mg/kg)	21.28 ± 0.15^{a}	80.71 ± 8.58^{b}	85.83 ± 1.66^{bc}	96.48 ± 1.35^{c}	95.52 ± 5.42^{c}

^{a,b,c} Values with different superscript letter in the same column are significantly different ($P<0.05$)
*K: Control with no *P. terebinthus,* A: Raw *P. terebinthus,* B: 100°C roasted *P. terebinthus,* C: 125°C roasted *P. terebinthus,* D: 140°C roasted *P. terebinthus*

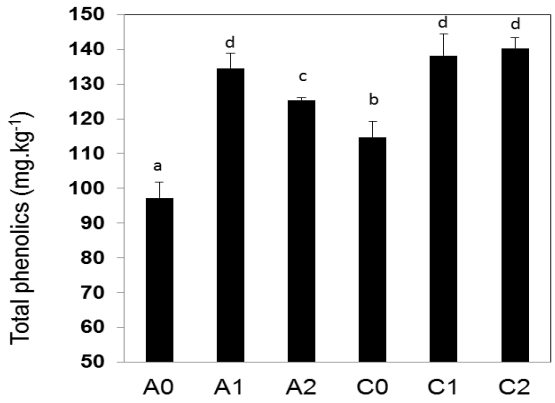
Impact of P. terebinthus incorporation stage and masking of total antioxidant activity



A0: Control with 5% raw P. terebinthus, A1: Milk solution with 5% raw P. terebinthus added before pasteurization, A2: Milk solution with 5% raw P. terebinthus added after pasteurization, C0: Control with 5% roasted (125°C 40 min) P. terebinthus, C1: Milk solution with 5% roasted (125°C 40 min) P. terebinthus added before pasteurization, C2: Milk solution with 5% roasted (125°C 40 min) P. terebinthus added after pasteurization. ^{a,b,c} Bars with different superscript letter are significantly different ($P<0.05$)

Figure 1. Change in the antioxidant capacity depending on incorporation stage.

Several studies showed the polyphenol-protein interactions and impact of those interactions on their AA (Arts et al., 2001; Xiao et al., 2011; Gallo et al., 2013). Milk proteins have an affinity to bind phenolic compounds which can mask the AA of those compounds and can reduce their bioavailability (Arts et al., 2001; Arts et al., 2002; Serafini et al., 2003; Stojadinovic et al., 2013). It has also been showed that AA of certain polyphenol–milk protein complexes affected by heat treatment (Kılıç Bayraktar et al., 2019). Therefore, we evaluated change in the AA by the stage of adding P. terebinthus before and after heat treatment of milk solutions; and we also evaluated the masking effect of ice cream on P. terebinthus. According to ABTS assay P. terebinthus adding stage didn't influence the AA; however, we observed differences between samples at DPPH assay (Fig. 1). Heat treatment (80°C 1 min) of milk solution together with P. terebinthus reduced its antioxidant capacity. Samples with P. terebinthus added after heat treatment had similar DPPH inhibition level with control. TPC of milk solutions were higher than the control (Fig. 2). Addition stage of roasted P. terebinthus didn't influence the TPC. Raw P. terebinthus on the other hand, had higher TPC when added to the milk solution before heat treatment.



A0: Control with 5% raw P. terebinthus, A1: Milk solution with 5% raw P. terebinthus added before pasteurization, A2: Milk solution with 5% raw P. terebinthus added after pasteurization, C0: Control with 5% roasted (125°C 40 min) P. terebinthus, C1: Milk solution with 5% roasted (125°C 40 min) P. terebinthus added before pasteurization, C2: Milk solution with 5% roasted (125°C 40 min) P. terebinthus added after pasteurization. [a,b,c] Bars with different superscript letter are significantly different ($P<0.05$)

Figure 2. Change in the total phenolics content depending on incorporation stage.

AA of both raw and roasted P. terebinthus were masked similarly in ice cream (Fig. 3). However different masking ratios were obtained from different measurement methods. Masking of AA by ice cream was much higher according to ABTS assay (30%) as compared to DPPH assay (9%). Differences between different test methods have been reported in previous studies as well (Skrede et al., 2004), therefore it is necessary to use more than one method when evaluating antioxidant capacity.

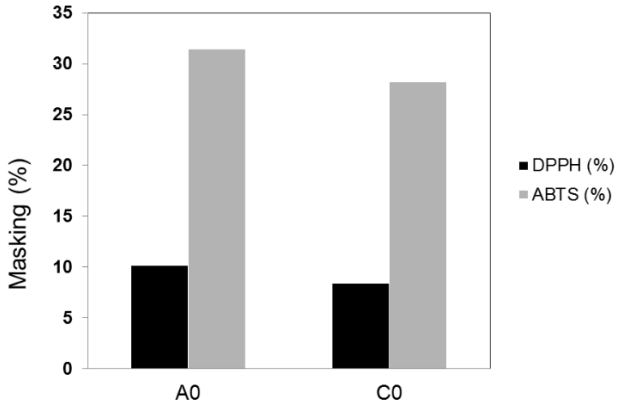


Figure 3. Masking of total antioxidant capacity of A0: 5% raw P. terebinthus and C0: 5% roasted (125°C 40 min) P. terebinthus when added in ice cream.

Sensory Analysis Results

Sensory analysis results are given in Table 3. No significant difference was observed between smoothness, gumminess, meltdown, iciness and taste and flavor of ice cream samples ($p>0.05$). Ice creams with P. terebinthus were found to be firmer than the K. It appears from the sensory evaluation that, the dark color of P. terebinthus ice creams was not liked, and received lower scores than the K. It was indicated in comments by most panelists that, although the taste and flavor of the P. terebinthus ice creams was good, the amount used was too high and therefore flavor was too intense. Reducing the P. terebinthus amount to an acceptable level would produce an ice cream with better color and flavor. General acceptability of roasted ice creams found better with C being slightly higher than the other P. terebinthus ice creams, while D and A received lower scores than K.

Table 3. Sensory evaluation of ice creams

Parameter	K	A	B	C	D
Color and appearance	8.70 ± 0.42^{a}	7.22 ± 0.255^{b}	7.04 ± 0.06^{b}	7.35 ± 0.21^{b}	7.66 ± 0.37^{b}
Firmness	6.30 ± 0.42^{b}	7.89 ± 0.05^{a}	8.00 ± 0.35^{a}	7.19 ± 0.16^{ab}	7.61 ± 0.62^{a}
Smoothness	5.73 ± 2.50^{a}	6.30 ± 1.13^{a}	6.95 ± 1.28^{a}	6.75 ± 0.71^{a}	6.82 ± 0.75^{a}
Meltdown	8.32 ± 0.02^{a}	7.80 ± 0.42^{a}	7.89 ± 0.30^{a}	7.76 ± 0.48^{a}	7.61 ± 0.27^{a}
Gumminess	7.18 ± 1.37^{a}	7.24 ± 0.19^{a}	7.34 ± 0.01^{a}	7.21 ± 0.41^{a}	7.22 ± 0.54^{a}
Iciness	8.10 ± 1.14^{a}	7.69 ± 1.43^{a}	8.17 ± 1.53^{a}	8.10 ± 1.55^{a}	7.62 ± 1.11^{a}
Taste and flavor	7.37 ± 0.11^{a}	6.93 ± 0.39^{a}	6.99 ± 0.15^{a}	7.31 ± 0.55^{a}	6.94 ± 0.33^{a}
General acceptability	8.29 ± 0.29^{a}	6.38 ± 0.25^{b}	7.21 ± 0.41^{ab}	7.42 ± 0.83^{ab}	6.46 ± 0.06^{b}

[a,b,c] Values with different superscript letter in the same column are significantly different ($P<0.05$)
*K: Control with no *P. terebinthus*, A: Raw *P. terebinthus*, B: 100°C roasted *P. terebinthus*, C: 125°C roasted *P.terebinthus*, D: 140°C roasted *P. terebinthus*

CONCLUSION

Significant differences were observed between AA and TPC of ice creams with P. terebinthus roasted at different temperatures. Ice creams with raw P. terebinthus had the lowest TPC and AA; and there was a proportional increase in both AA and TPC with the increase in heating temperature up to 125°C. Highest AA and better sensory properties were obtained by P. terebinthus roasted at 125°C for 40 min.

Increase in AA by roasting was due to the increase in TPC as well as the contribution of possible Maillard reaction products. Adding P. terebinthus to ice cream mix before heat treatment could reduce its AA according to our tests with milk solutions. About 30% of the AA of P. terebinthus was masked in the ice cream. The masking of the AA was presumably due to interactions between milk proteins and phenolics.

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An Alternative Gastronomic Product Obtained from Beans and Red Lentils: Hummus

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Abstract

Hummus, widely consumed in the Mediterranean and Middle East, is an appetizer made of chickpeas, lemon juice, tahini, garlic, olive oil, and various spices. The main ingredient of this appetizer variety is boiled chickpea, the most significant feature of which is its nutritional and filling nature. The preparation process for hummus, which involves a variety of legumes, is time-consuming and calorically rich. This study aimed to determine the sensory characteristics of hummus derivatives prepared from different legumes. In line with the objectives of this study, three different products were designed using different legumes (chickpeas, red lentils, and beans). A hedonic scale was used for sensory analysis of the prepared products, and this scale was applied to 11 panelists separately for each product. Upon examining the obtained data, it was found that hummuses made with red lentils had a greater preference. Additionally, research has revealed that products made with red lentils have certain advantages regarding time and nutrition.

Keywords: Beans, Red Lentils, Hummus, Gastronomic Product

Research article
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INTRODUCTION

At the end of the twentieth century, the world population, which was six billion, reached eight billion in the first quarter of the twenty-first century (TUIK, 2023). The rapid increase in world population has led to inadequate and inefficient use of resources, resulting in an increased demand for food (Oğan, 2022). Legume products rich in proteins play a significant role in meeting the demand for food. In addition to their high protein content, legume products are generally high in carbohydrates, low in fat, and possess nutritional properties (SPO, 2023). The highest production of field crops worldwide has been focused on cereals. Following cereals, legume products have followed this trend. Gulumser (2016:292), in his study citing Akcin (1988), classifies products used as legumes as "beans (Phaseolus vulgaris L.), chickpeas (Cicer arietinum L.), lentils (Lens culinary Medik, Lens esculenta Moench.), broad beans (Vicia faba L.), broad beans (Vigna sinensis L.), and peas (Pisum sativum L.)".

Therefore, legume products can be classified as dry beans, chickpeas, lentils, peas, mung beans, cranberry beans, or broad beans, depending on their production and consumption. Dry beans are the world's most widely produced grain legumes, followed by chickpeas and lentils (SPO, 2023). Consequently, the use of dry beans, chickpeas, and lentils as legume grain products has become widespread worldwide.

Middle Eastern and Mediterranean cuisines stand out for their use and consumption of grain legume products. Chickpeas are at the forefront of such products. Chickpea, a word of Arabic origin, humus (حمص), means chickpea. Humus, in the Türk dictionary, is a "dish prepared with well-mashed chickpeas, spices, and tahini." (TLA, 2023). Humus, a traditional dish, is made and consumed in many countries, including Arab countries, such as Iraq, Syria, Israel, Türkiye, Greece, and Armenia.

It is widely used in the Hatay and Mersin regions of Türkiye. The presence of a geographically marked product called Tarsus Hummus, specific to Mersin Province, is the leading indicator of this phenomenon. Although there is a commitment to traditional kitchen products, many factors are essential, such as creating new products, product development, enhancing flavors, and adding alternative features. In this study, we aimed to determine the sensory characteristics of the substitute products obtained from beans and lentils. In this way, an alternative product is obtained from these products and evaluated from a gastronomic perspective. In this context, the research aims to compare the sensory analysis of the hummus product made with beans and red lentils using the sensory analysis technique.

CONCEPTUAL FRAMEWORK

Regarding worldwide field crop production, grain groups have taken the lead. The second-most produced group of products, after grains, are legumes. Legumes are essential in human nutrition because of their protein (22%) and carbohydrate (7%) contents (Marinangeli & Jones, 2011; Sarıoğlu & Velioğlu, 2018; FAO, 2023). However, these mentioned ratios can vary depending on factors such as the type, maturity, gender, and cultivation conditions of the plant. Legumes contain essential nutritional features, including low calorie content, low fat, high fiber, valuable micronutrients, and antioxidant properties (Lopez-Amoro's, Hernandez & Estrella, 2006). Dry beans, chickpeas, and lentils are the most commonly produced legumes globally. The leading countries in dry bean, chickpea, and lentil production are India, Canada, Myanmar, China, Türkiye, Australia, the USA, Mexico, and Brazil (SPO, 2023).

The United Nations Food and Agriculture Organization (FAO) has declared February 10th as "World Pulses Day," underscoring the global significance of legumes. Türkiye is a significant player in global legume production, producing over a million tons of primary chickpeas, dry beans, and lentils (Anadolu Agency, 2023).

Akçin (1988) has highlighted the need for protein-rich foods to sustain vital human activities and nutrition. Therefore, legumes have emerged as a valuable food source for humans. Owing to their nutritional properties, efforts have been made to expand the use of grain legumes either alone or in combination with other food products (Amarowicz, 2010). Legumes have been used as staple foods in ancient civilizations. In addition to their nutritious and healthy characteristics, their low price makes them essential for the modern diet. Furthermore, it is possible to mention a dietary pattern focused on grains and legumes in underdeveloped and developing countries (Sarıoğlu and Velioğlu, 2018).

Beans, Lentils, Chickpeas, and Hummus Beans rank first in cultivation area and legume production worldwide (SPO, 2023). Sirat (2020:245) mentioned that bean production occurs in five regions: "Southern and Eastern Africa, Southeast and Western Europe, North, Central and South America, and East Asia." Fresh, canned, and dry beans were obtained. Its high protein content can address deficiencies in animal proteins, which contain a significant amount of protein (22-34%) (Abacı and Kaya, 2018). Lentils, one of the first cultivated plants worldwide, are single-year-old legumes. Lentil grains, such as beans, are rich in protein (25-28%). Owing to its cultivation in arid regions, it is a valuable product for both producers and regional economies. In Türkiye, red lentils (Southeastern Anatolia Region) and green lentils (Central Anatolia Region) are two varieties of cultivated lentils (Aydoğan, Karagül & Gürbüz, 2008; SPO, 2023; FAO, 2023). Chickpeas, the second most produced grain legume globally after beans, also known as "chana, gram, Bengal gram, garbanzo," is produced in kabuli and desi. Most (80%) of chickpea production is desi, with Kabuli widely produced in Türkiye. Like beans and lentils, chickpeas are a significant source of protein (20%). Therefore, these grain legumes can be considered significant, healthy, and economical protein sources for a balanced diet (Akçin, 1988) (see Table 1).

Table 1. Average Composition of Beans, Chickpeas and Lentils

Components	***Beans (dermason)***	***Chickpea (cob)***	***Lentil***
Energy (kcal)	281	334	299
Protein(g)	21.75	18.56	23.00
Carbohydrate(g)	29.42	41.35	36.62
Oil(g)	1.35	5.33	0.92
Total Dietary Fibre (g)	32.17	23.03	25.99
Ca (mg)	141	99	64
Fe (mg)	4.71	5.92	7.77
P (mg)	367	397	415
Vitamin B1 (mg)	0.796	0.572	0.159
Vitamin B2 (mg)	0.181	0.164	0.148
Niacin (mg)	4.141	3.146	4.613

Source: Sarıoğlu & Velioğlu (2018) *Values given are for 100 g of edible food.

Legumes hold a significant place in Turkish culinary culture. One such product is Hummus, made using chickpeas as its main ingredient. Hummus is a dish prepared by finely crushing chickpeas with spice and tahini. It is a traditional dish with these features and is made and consumed in many countries, including Arab countries, Iraq, Syria, Israel, Türkiye, Greece, and Armenia. It is widely used in the Hatay and Mersin regions of Türkiye. On November 1, 2017, it was certified by the Turkish Patent and Trademark Office under the name "Tarsus Hummus" as Protected Geographical Indication (PGI) in the dishes and soups group, based on the application of the Tarsus Chamber of Commerce and Industry (Türk Patent, 2023). In recent years, hummus has become a popular dish because of its harmony with different recipes and its ability to appeal to every palate. Hummus, bearing the characteristics of a type of appetizer, is generally served with lemon juice, garlic, salt, red pepper, cumin, and olive oil added to chickpeas and tahini.

MATERIAL and METHOD

This study used a sensory analysis technique to compare the sensory analysis of hummuses made from beans and red lentils. Two products (beans and red lentils) and a control product (chickpeas) were cooked simultaneously.

The research was conducted in the sensory analysis laboratory of the Gastronomy and Culinary Arts Department of Iskenderun Technical University between December 10-20, 2023. The sample group consisted of trained panelists who received sensory analysis training and were experts in this field. Presentations were made in portions to taste the products, and a panel environment was created during the sensory analysis process. Panelists were selected from among experts familiar with hummus culture. Eleven people participated in the application process, one of whom was the panel leader, and the others were panelists (Koppel, 2014). Although at least 80 people are required for consumer tests in sensory analysis, 10-20 panelists are considered sufficient for difference tests (Onoğlu and Elmacı, 2019; Sipos et al., 2021).

Considering the standards, the panelists were asked to evaluate the products cooked in different stoves. The objective sensory evaluation was ensured by not providing information about the products to the panelists. The sensory analysis used a sensory evaluation scale regarding the quality criteria. The sensory analysis scale, which specifies the distinctive features of each cooked food, was evaluated by panelists. The sensory evaluation measures a person's senses in response to a stimulus and involves three types of senses: qualitative, dimensional, and hedonic (pleasure). Thus, sensory evaluations are related to stimuli and response reactions (Gönül, 1983).

During sensory evaluation, the panelists were asked to examine the products regarding taste, smell, texture, and appearance. The sensory analysis used a 1-5 liking scale, and the panelists were asked to score each criterion. The products were evaluated in terms of four aspects using a hedonic scale: smell, texture, taste (appearance of a product), and overall liking. The hedonic scale assesses the panelists' preferences or liking/disliking situations (Onoğur and Elmacı, 2019). This scale was analyzed in different dimensions using spider web diagrams and graphs by averaging. Prior to the panel test, several sensory evaluation conditions were required. These are:

- The panelists had not eaten anything in the last three hours.
- The panelists had no sensitivity or allergic reaction to the products.
- The panelists participated in a previous sensory evaluation and attended a short training session.
- All panelists were experts in the field.
- Water was used after the evaluation of each product.
- The panelists did not use perfumes, scented creams, or colognes.

A 5-point scale was used in the sensory analysis scale to be filled out by the panelists; the level of "Appearance, Smell, Texture, Taste, and Overall Liking" of the product was asked. The relevant descriptors in the sensory analysis scale were scaled as follows:
1: "Strongly Disagree," 2: "Disagree," 3: "Neither Agree nor Disagree," 4: "Agree," 5: "Strongly Agree."

Table 2. Sociodemographic characteristics of the participants

Participants	Gender	Age	Educational Level	Occupation
P1	Male	26	Bachelor's Degree	Teacher
P2	Female	32	High School	Housewife
P3	Male	29	Bachelor's Degree	Teacher
P4	Male	51	High School	Housewife
P5	Male	42	Postgraduate Degree	Academician
P6	Female	33	Associate degree	Technician
P7	Female	27	Bachelor's Degree	Doctor
P8	Male	46	Bachelor's Degree	Doctor
P9	Male	43	High School	Worker
P10	Female	39	Bachelor's Degree	Engineer
P11	Female	41	High School	Housewife
P12	Male	42	Postgraduate Degree	Academician

Among the participants in the table, there were many differences in gender, age, and education level. First, when the gender distribution was examined, it was observed that there were six male and five female participants. This gender diversity implies that participants might have had different perspectives and experiences. In terms of age, the participants had a wide age range. This age distribution, ranging from 27 to 51 years, implies age-related differences in experiences within the group. Determining the average age can help us better understand the group dynamics. In terms of educational level, participants with different educational backgrounds ranging from high school to undergraduate, master's, and doctoral levels were present. Educational diversity indicates various areas of expertise and knowledge within a group. Looking at the participants' professions, it was observed that there were participants from different professions, such as teachers, homemakers, academics, technicians, doctors, engineers, and workers. This diversity of professions indicates a wide range of experience and expertise within the group (see Table 2).

Table 3. Humus formulation and preparation images

Product Code	Pulses Amount (gr)	Tahini (gr)	Lemon (ml)	Cumin (gr)	Garlic (gr)	Water (ml)	Salt (gr)	Olive Oil (ml)	Chilli Pepper (gr)
Chickpea	240	70	80	10	10	105	15	15	6
Beans	235	70	80	10	10	105	15	15	6
Lentil	250	70	80	10	10	95	15	15	6

Chickpea			**Lentil**
Beans			**Hummus Products**

The quantities of ingredients used in this recipe reflect a similar approach for the three legume types. First, 240 g of legumes, 70 g of tahini, 80 ml of lemon juice, 10 g of cumin, 10 g of garlic, 105 ml of water, 15 g of salt, 15 ml of olive oil, and 6 g of red pepper flakes were used (see Table 3).

Similarly, the Bean recipe exhibits noticeable similarities. A delicious mixture was obtained using 235 g of beans, 70 g of tahini, 80 ml of lemon juice, 10 g of cumin, 10 g of garlic, 105 ml of water, 15 g of salt, 15 ml of olive oil, and 6 g of red pepper flakes.

Lentils also feature a similar list of ingredients. A rich flavor profile was achieved using 250 g of lentils, 70 g of tahini, 80 ml of lemon juice, 10 g of cumin, 10 g of garlic, 95 ml of water, 15 g of salt, 15 ml of olive oil, and 6 g of red pepper flakes.

The preparation and presentation stages of the hummus products, including visuals, are presented in Table 3. While each recipe contained the same components, they were carefully prepared with balanced ingredients to bring out the unique flavors of the legumes. Thus, it is evident that each recipe is interconnected with similar elements yet possesses distinctive flavor profiles.

Table 4. Mean nutritional values and total preparation times of pulse products

Product Code	Energy (Kcal)	Protein (gr)	Oil (gr)	Carbohydrate (gr)	Fiber (gr)	Starch (gr)	Preparation Time (min)
Chickpea	334	18,56	5,33	41,35	23,03	30,98	493
Beans	281	21,75	1,35	29,42	32,17	21,64	381
Lentil	322	25,81	1,57	41,94	18,67	40,95	33

Chickpeas had an energy content of 334 kcal and a high protein ratio (18.56 g). It is also rich in fiber and can have positive effects on the digestive system. However, the preparation time was quite long compared to the other samples (493 min). Beans with low fat and high fiber contents have emerged as a healthy choice. In particular, its fiber ratio (32.17 gr) can support the digestive system and provide a long-lasting feeling of fullness. The preparation time was shorter than that of chickpeas (381 min).

Lentils with the highest protein content (25.81 g) stood out and had a short preparation time of only 33 min. Additionally, its high starch content provides energy-providing features. Lentils, which can be cooked in a shorter time than other legumes, are a practical choice. This table offers options for individuals with different nutritional needs and preparation-time preferences when determining their dietary habits and meal planning (see Table 4).

RESULTS

Graph 1 shows the arithmetic mean values for the odor parameters of hummus made from beans, chickpeas, and red lentils (undesirable odor, garlic odor, cumin odor, and tahini odor). The average values of these parameters are expected to be in the range of 2–4.

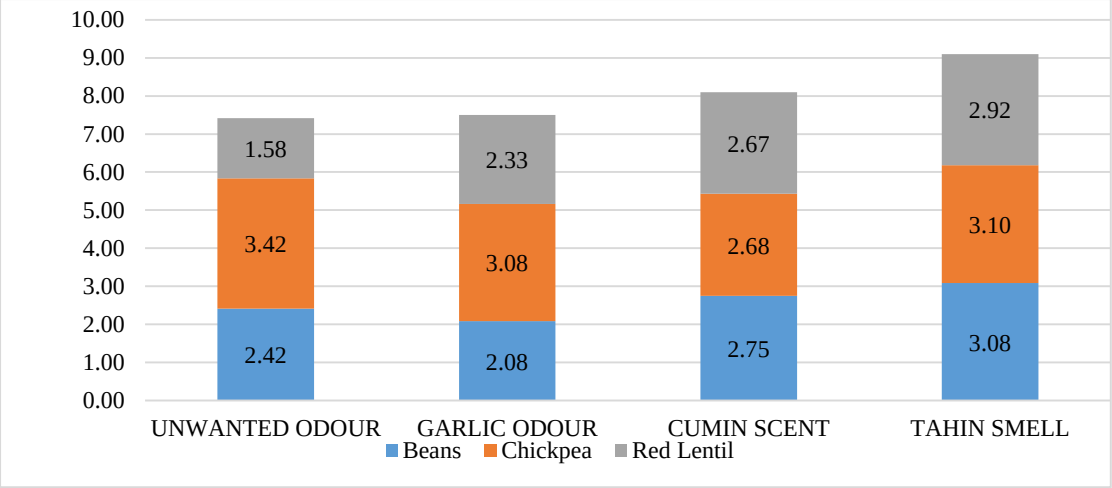
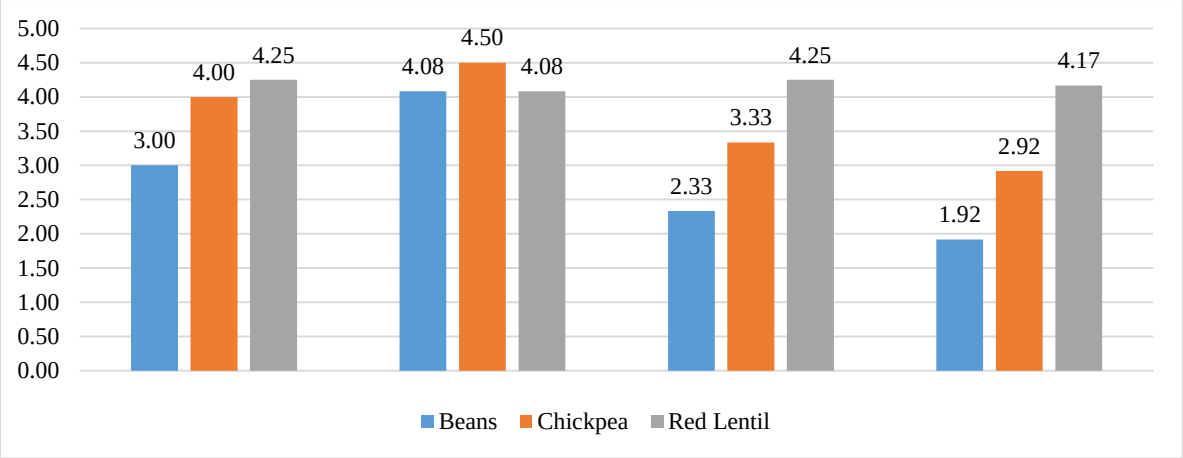


Figure 1. Sensory evaluation results regarding the aroma of hummus product

In Graph 1, the arithmetic mean values related to the aroma parameters of different legume types, such as beans, chickpeas, and red lentils, were determined: unwanted odor (X=2.47), garlic odour (X=2.50), cumin scent (X=2.70), and tahin scent (X=3.03). Four different aromas were identified for each legume and evaluated on a specific scale. Unwanted Odor: Compared to beans, chickpeas, and red lentils, chickpeas have a higher value, with scores of 2.42 for beans, 3.42 for chickpeas, and 1.58 for red lentils. Among the three legume types, chickpeas had the highest unwanted odor value. Garlic Scent: Chickpeas had the highest value compared to beans and red lentils. Beans scored 2.08, chickpeas scored 3.08, and red lentils scored 2.33. Once again, chickpeas were identified as having the highest garlic scent value among the legumes. Cumin Scent: Among beans, chickpeas, and red lentils, beans had the highest value. Beans scored 2.75, chickpeas scored 2.68, and red lentils scored 2.67. Beans have the highest cumin scent value among these three legume types, although chickpea and red lentil values are quite close. Tahini Scent: Chickpeas scored the highest compared with beans and red lentils. Beans = 3.08, chickpeas = 3.10, and red lentils = 2.92. Chickpeas had the highest tahini scent. Therefore, chickpeas generally receive higher scores than others in unwanted odor, garlic scent, and tahini scent, whereas beans stand out for cumin scent.

Red lentils usually had lower values than the other two legume types. These evaluations can be used to compare the sensory olfactory profiles of legumes. As a result of the evaluation, it was found that in the case of hummus, the average desired value of descriptors is close to "3"/"neither agree nor disagree" (max. X=2.68), indicating that compared to other products, red lentils have fewer unwanted odors. Graph 2 provides arithmetic mean values for spreadability, lumpiness, consistency, and homogeneity changes in the texture of hummus products from beans, chickpeas, and red lentils. These average values were expected to be in the range of 3–5.



*From left to right; spreadability, granularity, consistency, and homogeneity

Figure 2. Sensory evaluation results of humus product textures

Examining Graph 2 determined the average values regarding spreadability, granularity, consistency, and homogeneity changes in the textures of different legume types, including beans, chickpeas, and red lentils. The average values are as follows: spreadability (X=3.75), granularity (X=4.22), consistency (X=3.31), and homogeneity (X=3.00). The sensory features of the products were evaluated based on the following four criteria: spreadability, granularity, consistency, and homogeneity.

Spreadability: Red lentils (4.25) obtained the highest score, whereas chickpeas (4.00) and beans (3.00) received lower scores.

Granularity: Chickpeas scored the highest (4.50), whereas beans (4.08) and red lentils (4.08) showed similar granularity levels.

Consistency: Red lentils achieved a significantly higher score (4.25) compared to others, chickpeas (3.33) were rated with moderate consistency, and beans had the lowest consistency score (2.33).

Homogeneity: Red lentils received the highest score (4.17), chickpeas had moderate homogeneity (2.92), and beans had the lowest homogeneity score (1.92).

These evaluations provided important information for understanding the sensory characteristics of each product. Red lentils excel in spreadability, consistency, and homogeneity, while chickpeas stand out in granularity. Beans, on the other hand, are generally evaluated with lower scores. The average values of each product closely align with the desired/expected value (3.57).

Graph 3 presents the average values for the flavor parameters of the humus product, including undesired taste, sourness, acidic taste, spiciness, bitterness, saltiness, sesame flavor, sweetness, oiliness, and aftertaste. The average values for these parameters are expected to be within the range of 1–5.

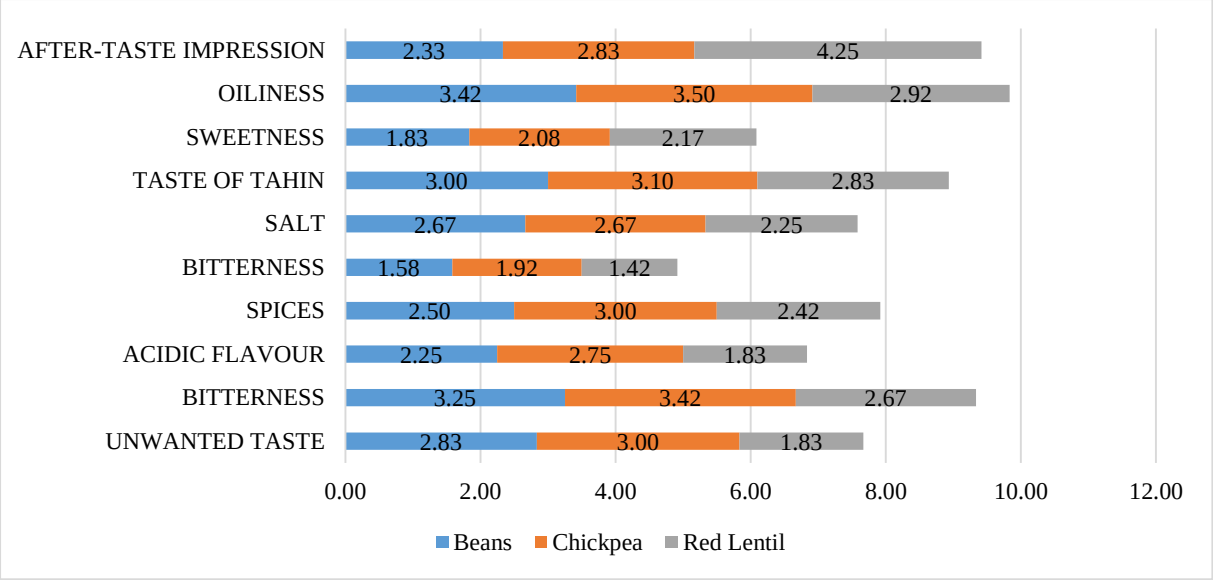


Figure 3. Sensory evaluation results related to the taste of hummus products.

In Graphic 3, the arithmetic mean values for the taste parameters of different legume types, such as beans, chickpeas, and red lentils, are determined to be unwanted taste (X=2.56), sourness (X=3.11), acidic flavor (X=2.28), spiciness (X=2.64), bitterness (X=1.64), saltiness (X=2.53), tahini flavor (=2.98), sweetness (X=2.03), oiliness (X=3.28), and post-taste impression (X=3.14). The graphic shows the sensory analysis results of the three different legume types. Ten different criteria and evaluation scores were used for the analysis. Unwanted Taste: Beans scored 2.83, chickpeas scored 3.00, and red lentils scored 1.83. This assessment shows that red lentils show more favorable results regarding unwanted tastes than others. Sourness: Chickpeas scored 3.42, beans scored 3.25, and red lentils scored 2.67. In this case, chickpeas had the highest sourness scores. Acidic Flavor: Beans scored 2.25, chickpeas scored 2.75, and red lentils scored 1.83. The red lentils, which had the lowest score, differentiated themselves in terms of their acidic flavor. Spiciness: Chickpeas scored 3.00, beans scored 2.50, and red lentils scored 2.42. Chickpeas ranked the highest in terms of spiciness. Bitterness: Red lentils scored 1.42, chickpeas scored 1.92, and beans scored 1.58. Red lentils, with the lowest scores, had a lighter taste profile than the others. Saltiness: Beans and chickpeas scored 2.67, and red lentils scored 2.25. Tahini Flavor: Chickpeas scored 3.10, beans scored 3.00, and red lentils scored 2.83. Chickpeas slightly lead to a tahini flavor compared with the others. Sweetness: Red lentils scored 2.17, chickpeas scored 2.08, and beans scored 1.83. Red lentils had the highest sweetness score. Oiliness: Chickpeas scored 3.50, beans scored 3.42, and red lentils scored 2.92. Chickpeas stand out in oiliness compared to the others. Post-taste Impression: Beans scored 2.33, chickpeas scored 2.83, and red lentils scored 4.25. Red lentils obtained a higher score on post-taste impressions than others.

This sensory analysis table, containing ten criteria used to compare various flavor characteristics of three different legume products, highlights red lentils as a preferable option in terms of the first criterion, "unwanted taste." Chickpeas excel in sourness and exhibit an acidic profile. Additionally, in the "acidic flavor" criterion, red lentils exhibited a lighter flavor profile than others. Chickpeas stand out in the "spiciness" criterion, indicating more pronounced spiciness than other legumes. Regarding "bitterness," red lentils, with the lowest score, suggest a milder taste profile. In the "post-taste impression" criterion, red lentils scored higher than the others, implying a prolonged flavor experience.

On the other hand, in the "oiliness" criterion, chickpeas received a slightly higher score than the other legumes. In conclusion, these observations demonstrated that each legume type possesses unique sensory characteristics. The panelists considered these diverse features based on their preferred flavor profiles. Graphic 4 presents the arithmetic mean values for the hummus product's visual parameters (brightness, color, homogeneous appearance). The expected average values of these parameters were 3–5.

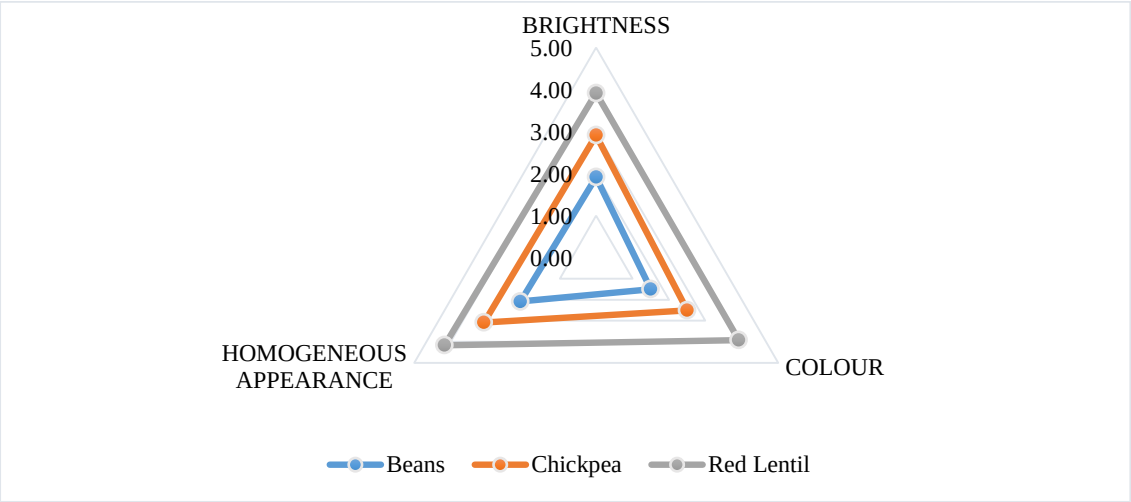


Figure 4. Sensory evaluation results related to the appearance of hummus products.

In Graph 4, the average values for the image parameters of different legume types, namely beans, chickpeas, and red lentils, are represented as brightness (X=2.92), color (X=2.64), and homogeneous appearance (X=2.78). Brightness: Beans, 1.92; chickpeas, 2.92; and red lentils, 3.92. This indicates that the red lentils have a higher brightness level than the others. Color: Beans 1.50, chickpeas 2.50, and red lentils had color scores 3.92. These results reveal that red lentils have a more distinct and saturated color than the other two products. Homogeneity: Beans and chickpeas score 2.08, while red lentils score 4.17.

This suggests that the elements within the red lentils were distributed more evenly, displaying a homogeneous appearance. In conclusion, these results can provide essential information to consumers or producers who wish to compare and prefer the visual and structural characteristics of products. For instance, a consumer may choose a product with higher values in brightness and color. In contrast, a producer may evaluate various production processes to enhance the homogeneous appearance of their products.

Graph 5 shows the arithmetic mean values for overall liking levels regarding the appearance, smell, texture, and taste of the produced hummus products. The expected range for these overall liking levels was 2–4.

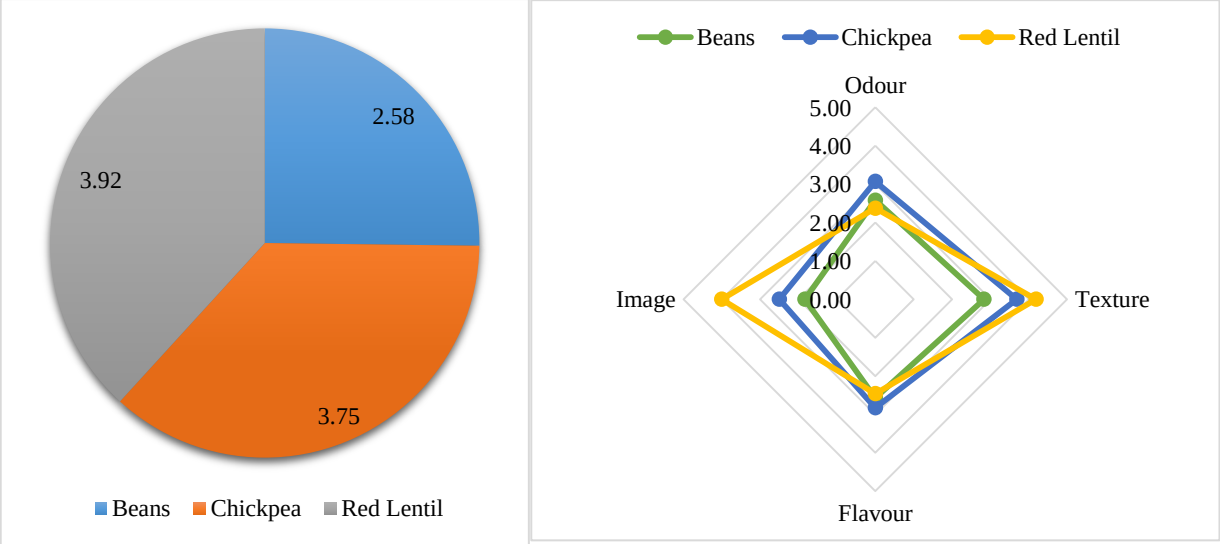


Figure 5. Sensory evaluation results for general liking level.

When Graphic 5 was examined, the average values of the appearance/image, aroma/odour, texture, and taste of bean, chickpea, and red lentil products from hummus products were as follows: bean (X=2.58), chickpea (X=3.75), and red lentil (X=3.92). Accordingly, in terms of aroma, texture, and taste, red lentils are more liked than others, whereas beans have received less preference. These results indicate that the average values of appearance, aroma, texture, and taste of the respective products in terms of overall liking were in an unexpected range. In this context, it can be stated that a product made using red lentils can be used as a substitute for hummus made initially with chickpeas.

The evaluations showed the perception differences between the types for each feature. Regarding aroma, the beans had a moderate value of 2.58 points. Chickpeas achieved the highest aroma score (3.07 points, whereas red lentils had the lowest aroma score (2.38 points. When examined in terms of texture, beans have the lowest texture score of 2.83 points. Chickpeas received a moderate value of 3.69 points, while red lentils had the highest texture score of 4.19. In terms of taste, chickpeas received the highest score of 2.83, whereas beans and red lentils were determined to have medium and low taste values of 2.57 and 2.46 points, respectively. Finally, red lentils stood out in the appearance feature, with the highest score of 4.00. Beans had a moderate score of 2.50, and chickpeas had the lowest appearance score of 1.83.

CONCLUSION

The use and consumption of legumes such as dry beans, chickpeas, and lentils are widespread worldwide. The kitchens where these legumes are most commonly used are in the Middle East and the Mediterranean region. Among the legume varieties, beans, chickpeas, and lentils are the most preferred. In the kitchen, many aspects are essential, such as creating innovative products, developing products, enhancing product flavors, providing alternative product features, and creating substitute products. This study aimed to compare the sensory analysis techniques of the aroma, color, flavor, and texture of products made using beans and red lentils. In this study, two products (beans and red lentils) were prepared in addition to chickpea hummus (control hummus). The products were evaluated by 11 panelists, experts in four aspects: aroma, texture, flavor (visual appearance of a product), and overall liking.

It was observed that red lentils are prepared more quickly and easily than others in the preparation time of products obtained from chickpeas, beans, and red lentils. Chickpeas stand out in unwanted odor, garlic odor, and tahini odor, whereas beans stand out in cumin odor. The red lentils had low values in terms of aroma characteristics. Therefore, hummus products made from red lentils have a neutral aroma. Red lentils stand out in spreadability, consistency, and homogeneity, whereas chickpeas stand out in lumpiness. Beans, however, were generally evaluated with lower scores. Therefore, it can be said that the texture properties of the hummus product made from red lentils are better. Products obtained from chickpeas, beans, and red lentils also exhibit unique taste characteristics. Therefore, although each product has its unique taste, red lentils stand out in terms of taste. Again, it was found that red lentils were visually superior to the other products.

Finally, the ranking of chickpea, bean, and red lentil products in terms of overall liking levels for appearance, aroma, texture, and flavor was determined as red lentils, chickpeas, and beans. The study's results revealed that red lentils can be used as a substitute for chickpeas used in hummus. It has also been determined that using red lentils provides some advantages to consumers and producers regarding time and functionality. Future studies aimed at enhancing the functionality of meals made with substitute products will contribute to the literature and menu planners. In addition, it is anticipated that the study will constitute a resource for other research in terms of product development using alternative products in kitchens.

CONFLICT of INTEREST

The authors have no financial or personal conflicts of interest that could influence the content or interpretation of the research presented in this paper. The research was conducted in an unbiased manner and the results are reported objectively. In the research, the conceptual framework and fieldwork were carried out jointly by the authors. Therefore the contribution rates of the authors are equal and there is no conflict of interest between them.

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Effect of Chitosan Coating Supplemented with Olive Leaf Extract on Oxidative Quality of Fish

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Abstract

In this study, the effect of chitosan coating supplemented with olive leaf extract on the oxidative quality of rainbow trout fillets at 4°C for 15 days of storage were determined. For this purpose, samples were divided into five groups entitled as; fillets immersed in chitosan coating (Cc), fillets immersed in chitosan coating with 0.5%, 1% and 2% olive leave extract named as O0.5, O1 and O2 and fillets without coating (C). The highest pH values were found in the C and Cc groups during storage, while the lowest pH values were found in the O2 group. Peroxide value, which is the principal oxidation products, increased in all groups until at the end of the storage and the highest values were found in C and Cc groups, respectively (9.00 meq/kg and 8.00 meq/kg). The lowest peroxide value was determined in O2 group as 5.50 meq/kg. At the beginning of storage, TBARS value of rainbow trout fillets was 0.16 mg MDA/kg showed increase in all groups at the end of the storage period. The C and Cc groups had the highest TBARS value which increased throughout the storage and reached 2.07 and 1.92 mg MDA/kg at the end of storage, respectively. Rainbow trout fillets immersed in chitosan solution enhanced with 2% OLE had TBARS values of 1.31 mg MDA/kg, which was found to be considerably low ($P<0.05$). As a result, it was determined that the supplementation of olive leaf extract raised the effectiveness of chitosan and reduced lipid oxidation in rainbow trout fillets.

Keywords: Rainbow trout, chitosan, edible coating, olive leaf extract, lipid oxidation

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INTRODUCTION

Consumers want healthy nutrient dense food due to their concern regarding food quality and their awareness about negative ecological effects of non-biodegradable food packaging which is leading to high demand of fresh fish (Angiolillo et al., 2018). Though, fish is very perishable, thus normally sold as a processed or frozen product. Unfortunately, frozen fish does not completely prevent the degradation of fish lipids. Few countries have banned the usage of chemical preservatives in foodstuff. To cope up with such issues, new approaches of preservation of food have been established, which includes active packaging like coatings or films that may control the transfer of water and gases, hence decrease microbial growth (Hassan et al., 2018).

The major purpose of food packaging is to inhibit the contact to deterioration factors that includes the effects of microbes, temperature, humidity and oxygen to reduce the nutritional loss, hence maintains quality and extends the shelf life. Though, food packaging provides additional functions like increasing communication and convenience to customers and marketing of the packed item. Various advanced packaging techniques have been established in preservation of meat like modified atmospheric packaging, vacuum packaging, edible packaging, intelligent and active packaging (Gertzou et al., 2017; Fang et al., 2017).

In recent times, edible films and coatings have fascinated much attention from scientists. In comparison with conventional packaging, edible coating or film is directly applied on food surface to maintain quality and extends shelf-life. Moreover, the edible packaging material is mostly derived organically, which have biodegradable, biocompatible, non-toxic and bioactive properties all together that might not be available in artificial packaging materials (Mihai and Popa, 2015). Growing customer demand for high quality nutritional and safe foods with long shelf lives, as well as environmental awareness of limited natural resources and the impact of packaging waste on the environment, have ignited significant interest and innovative research activity in edible packaging in the food industries (Janjarasskul and Krochta, 2010).

Enrobing with any sort of thin layer on food items for shelf-life extension that might be consumed along with food is referred as an edible coating or film. The films and coatings are applied to food with the intention to enhance the shelf life, nutritional and organoleptic features of food (Akram et al., 2019). Edible film and coating provides physical shield to save food items from mechanical loss, and also from chemical and biological events (Min et al., 2005). Edible films are made from sustainable resources, and mostly are more degradable than synthetic materials. Non-biodegradable and non-renewable packaging resources have some thoughtful environmental disadvantages. They are considered as a main cause of environmental waste and pollution by scientists (Ramos et al., 2013).

Edible coatings or films if not used along with food, may contribute to reduce environmental pollution (Embuscado and Huber, 2009). The main purpose of packaging is to save food from chemical, physical, biological factors which cause food spoilage, extend the useful effect of food processing, maintains the quality of food along with extended shelf life (Marsh and Bugusu, 2007). The purpose of this study is to determine the oxidative stability of rainbow trout fillets by using chitosan coating supplemented with different concentrations of olive leaf extract.

MATERIAL and METHOD

Materials

In this research, rainbow trout (*Oncorhynchus mykiss*) fillets, weighing 204.28 ± 8.31g with length of 24.51 ± 0.79 cm, were transported from a fish market in Niğde to the research laboratory within 1 hour in styrofoam boxes filled with ice. Commercial chitosan which produced by the deacetylation of chitin, a component of shrimp shells was obtained from Sigma-Aldrich. The olive leaves used in this study were harvested from olive trees in İzmir, Turkey in December 2021.

Methods

Extraction process of olive leaf

Olive leaves were washed two times in running tap water and dried at 45^{o}C for 48 hours. Dried olive leaf was grounded into powder with a blender. For extraction process, 10 g of olive leaf powder was dissolved in 100 mL of 70% ethanol in a flask, subjected to magnetic stirrer for 2 hours at room temperature. Afterwards, the extract was filtered by using Whatman no. 3 filter paper and evaporation was done in rotary evaporator under vacuum (IKA, HB 10 digital, Germany) at 45°C (Oomah et al., 2008).

Preparation of chitosan solution and application to rainbow trout fillets

Chitosan coating solution was prepared by the method of Ojagh et al. (2010). Chitosan solution was made by adding 1 gram of chitosan powder in 100 mL of 1 % v/v acetic acid solution and was stirred for 3 h at room temperature, followed by filtration through a Whatman no. 3 filter paper (Ojagh et al., 2010). Olive leaf extract (OLE) was added to the coating solution in three different concentrations (0.5%, 1.0% and 2.0%) (by volume per mass of chitosan). Fillets were categorized into five groups as fillets without coating (C), fillets with chitosan solution (CCh), fillets coated with chitosan solution supplemented with 0.5% OLE (O0.5), fillets coated with chitosan solution supplemented with 1.0% OLE (O1) and fillets coated with chitosan solution supplemented with 2.0% OLE (O2). Total number of rainbow trout fillets used in this study was twenty-five. For each coated group, five fillets weighing approximately 900 g were dipped in the coating solution for 30 seconds and then permitted 2-minute drain time followed by an another immersion for 30 seconds. All the samples were placed in a sterile foam plate and covered with stretch film, then stored in refrigerator at 4 °C for 15 days. Analyses were conducted every three days during the storage period.

pH measurement

In pH measurement, pH-meter probe (Thermo Scientific Orion 2-star, Germany) was immersed into the homogenized samples, mixed with distilled water in a 1: 1 ratio (Manthey et al., 1988).

Peroxide value analysis (PV)

Peroxide value analysis was carried out by following the method (AOAC, 1990). 1g of fish oil put in 30mL chloroform-glacial acetic acid solution (3chloroform and 2glacial acetic acid) and then 1mL of saturated potassium iodide solution was added. The solution after mixing was kept for 5 minutes in some dark place. Then, 30mL distilled water and few starch drops was added and titration was done with 0.1M sodium thiosulfate ($Na_2S_2O_3$) solution. Peroxide value of samples was calculated by using below formula which is expressed in meq/ kg.

PV (meq / kg) = K x (V-V0) x 12.69 x 78.8 / w
K - used on titration $Na_2S_2O_3$' starch concentration (mol / lt),
V - titration $Na_2S_2O_3$' starch amount in mL,
w - weight of the oil in grams

Thiobarbituric acid reactive substances (TBARS) analysis

The malondialdehyde in samples colored with TBA reagent, so spectrophotometric tests were performed (AOCS, 1998). The same amount of TBA reagent was combined with 0.1g of fish oil dissolved in n-butanol. It was held in 95°C water bath for 2 hours. At a wavelength of 530 nm, rapidly cooled samples were examined in a spectrophotometer, and the findings computed using the formula below, expressed as mg malondialdehyde/kg sample.

TBA = 50 x (lipid absorbance – blank absorbance) / sample weight (mg)

Statistical analyses

All analyses were carried out in duplicate. Statistical analysis was done by using SPSS (Statistical Analysis System, Cary, NC, USA) software and multiple comparison tests were performed on several applications.

RESULTS and DISCUSSION

pH

Table 1 shows the differences in pH values of rainbow trout fillets coated with 0.5%, 1% and 2% olive leaf extract and chitosan.

Table 1. Changes in pH of rainbow trout fillets immersed in chitosan coating supplemented with different concentration of olive leaf extract

	Treatments				
Storage (Day)	**C**	**Cc**	**O0.5**	**O1**	**O2**
0	6.31 ± 0.01^{Af}	6.31 ± 0.01^{Af}	6.31 ± 0.01^{Af}	6.31 ± 0.01^{Af}	6.31 ± 0.01^{Ae}
3	6.39 ± 0.01^{Ae}	6.36 ± 0.00^{Be}	6.36 ± 0.01^{Be}	6.33 ± 0.01^{Ce}	6.32 ± 0.01^{Ce}
6	6.89 ± 0.01^{Ad}	6.88 ± 0.01^{Ad}	6.49 ± 0.01^{Bd}	6.45 ± 0.01^{Cd}	6.41 ± 0.01^{Dd}
9	7.21 ± 0.01^{Ac}	7.21 ± 0.01^{Ac}	6.61 ± 0.01^{Bc}	6.56 ± 0.00^{Cc}	6.47 ± 0.01^{Dc}
12	7.40 ± 0.01^{Ab}	7.41 ± 0.01^{Ab}	6.81 ± 0.01^{Bb}	6.78 ± 0.01^{Cb}	6.68 ± 0.01^{Db}
15	7.70 ± 0.01^{Aa}	7.69 ± 0.01^{Aa}	6.94 ± 0.01^{Ba}	6.85 ± 0.01^{Ca}	6.81 ± 0.01^{Da}

Means indicated by different capital letters in the same row differ significantly ($P < 0.05$). Means indicated by different lowercase letters in the same column differ significantly ($P < 0.05$). C: control, Cc: fillets with chitosan coating, O0.5: fillets immersed in chitosan coating supplemented with 0.5% of OLE, O1: fillets immersed in chitosan coating supplemented with 1% of OLE, O2: fillets immersed in chitosan coating supplemented with 2% of OLE.

At the beginning of storage, pH of rainbow trout fillets was 6.31 and by the end of storage it became high in all groups. The rises in pH are linked to the generation of volatile amines as a result of microbes (Huss, 1995). Cobb (1977) and Finne (1982), on the other hand, cited enzymatic ammonia generation as a source of pH rises. C, Cc, and groups immersed in chitosan solution with OLE concentrations showed significant differences ($P<0.05$). The highest pH values in the C and Cc groups were 7.70 and 7.69, respectively, after 15 days of storage, while the lowest pH value in the O2 group was 6.81.

According to Ludorf and Mayer (1973) and Ozyurt et al. (2017), pH value for fresh fish should be between 6.8 and 7.0. The pH levels of OLE 0.5%, 1%, and 2% were remained within acceptable limits for fresh fish at the end of storage, but the values of C and Cc had above the limit for fresh fish after the 6th day of storage. Although the pH value is not a reliable indicator of fish deterioration, it can be used as a guideline for maintaining fish quality (Ruiz-Capillas and Moral, 2001). The accumulation of alkaline chemicals caused by the breakdown of nitrogenous compounds by spoilage bacteria activity results in an elevation in pH (Chaijan et al., 2005; Li et al., 2012). Guan et al. (2019) reported that addition of sage, oregano and grape seed extract treatment steadied the pH in hairtail fish balls during storage at 4°C. Fadıloğlu and Emir Çoban (2018) observed that pH value of chitosan + sumac effectively low pH value compared to other groups.

Peroxide value (PV)

The differences in PV of rainbow trout fillets immersed in chitosan coating incorporated with olive leaves extract concentration of 0.5%, 1% and 2% are given in Table 2.

Table 2. Peroxide value (PV) of rainbow trout fillets immersed in chitosan coating supplemented with different concentration of olive leaf extract (meq/kg)

Storage (Day)	C	Cc	O0.5	O1	O2
0	1.00 ± 0.00^{Ad}	1.00 ± 0.00^{Ac}	1.00 ± 0.00^{Ac}	1.00 ± 0.00^{Ac}	1.00 ± 0.00^{Ac}
3	1.00 ± 0.00^{Ad}	1.00 ± 0.00^{Ac}	1.50 ± 0.71^{Ac}	2.00 ± 0.00^{Ac}	1.50 ± 0.71^{Ac}
6	2.50 ± 0.71^{Abc}	3.00 ± 0.00^{Ab}	2.00 ± 0.00^{Abc}	1.50 ± 0.71^{Bc}	1.50 ± 0.71^{Bc}
9	6.50 ± 0.71^{Ab}	6.50 ± 0.71^{Aa}	6.00 ± 0.00^{Ab}	4.50 ± 0.71^{Bb}	4.00 ± 0.00^{Bb}
12	7.50 ± 0.71^{Ab}	7.50 ± 0.71^{Aa}	6.00 ± 0.00^{Bb}	5.50 ± 0.71^{Bab}	5.00 ± 0.00^{Bab}
15	9.00 ± 0.00^{Aa}	8.00 ± 1.41^{Aba}	7.50 ± 0.71^{ABCa}	6.00 ± 0.00^{BCa}	5.50 ± 0.71^{Ca}

Means indicated by different capital letters in the same row differ significantly ($P < 0.05$). Means indicated by different lowercase letters in the same column differ significantly ($P < 0.05$). C: control, Cc: fillets with chitosan coating, O0.5: fillets immersed in chitosan coating supplemented with 0.5% of OLE, O1: fillets immersed in chitosan coating supplemented with 1% of OLE, O2: fillets immersed in chitosan coating supplemented with 2% of OLE.

At the beginning, PV value of rainbow trout fillets was observed as 1 meq/kg and increased in all groups during the storage period. The PV values of chitosan coated samples suplemented with 0.5%, 1% and 2% concentration of OLE were recorded as 7.50, 6.00 and 5.50 meq/kg, respectively, while 9.00 and 8.00 meq/kg were recorded in control and chitosan groups at 15th day of storage. The highest PV was observed in control group compared to chitosan coated samples, while the lowest peroxide value was observed significantly ($P<0.05$) in rainbow trout fillets immersed in chitosan solution enriched with 2% OLE because of powerful antioxidant activity. PV is a measurement of peroxides and hydroperoxides that occurs in the early stages of lipid oxidation and is extensively used for oxidative rancidity (Alsaggaf et al., 2017). Peroxides, the major product of lipid oxidation are volatile molecules that produce aldehydes, ketones, and alcohols, which cause off flavor in products (Hamilton et al., 1998).

In bovine muscle model systems Hayes et al. (2009) discovered that olive leaf extract had a positive linear dose response effect, meaning that the greater the addition level the stronger the antioxidant activity. According to Bouaziz et al. (2008), olive leaf extract at a concentration of 400 ppm demonstrated excellent antioxidant activity and was effective in preventing oil rancidity. Carpenter et al. (2006) discovered that olive leaf extract significantly reduces oxidative stress in cells. Peroxide values are classed as "verygood" if they contain less than 2 mmol O_2/kg of fish, "excellent" if they contain up to 5 mmol/kg of fish, and "acceptable" if they include 8–10 mmol/kg of fish (Varlık et al., 1993). A value of fewer than 5 meq/kg of peroxide should indicate good quality fish lipids (Hamilton et al., 1998). As a result, the peroxide value at 0 day for all samples was 1.00 meq/kg, which is considered excellent. The control and chitosan coating (Cc) groups increased to 9 and 8 meq/kg, respectively, while the O2 group was deemed good at the end of the storage period. In the current investigation, in order to prevent lipid oxidation in rainbow trout fillets during refrigerated storage usage of 2% OLE was substantially more successful.

Thiobarbituric acid reactive substances (TBARS)

TBARS values difference of rainbow trout fillets immersed in chitosan coating incorporated with olive leaves extract concentration of 0.5%, 1% and 2% are given in Table 3.

Table 3. Change in TBARS of of rainbow trout fillets immersed in chitosan coating supplemented with different concentration of olive leaf extract (mg MDA/kg)

Storage (Day)	C	Cc	O0.5	O1	O2
0	0.16 ± 0.01^{Af}	0.16 ± 0.01^{Ae}	0.16 ± 0.01^{Ad}	0.16 ± 0.01^{Ad}	0.16 ± 0.01^{Ab}
3	0.95 ± 0.01^{Ce}	1.08 ± 0.03^{Bd}	0.97 ± 0.00^{Cc}	1.25 ± 0.01^{Ab}	1.12 ± 0.02^{Ba}
6	1.31 ± 0.03^{Ad}	1.20 ± 0.05^{Ac}	1.21 ± 0.08^{Ab}	1.00 ± 0.02^{Bc}	0.97 ± 0.02^{Ba}
9	1.49 ± 0.00^{Bc}	1.67 ± 0.04^{Ab}	1.28 ± 0.04^{Cb}	1.07 ± 0.02^{Dbc}	1.02 ± 0.02^{Da}
12	1.70 ± 0.07^{Ab}	1.70 ± 0.04^{Ab}	1.30 ± 0.03^{Bb}	1.20 ± 0.13^{Bb}	1.16 ± 0.10^{Ba}
15	2.07 ± 0.01^{Aa}	1.92 ± 0.04^{ABa}	1.80 ± 0.02^{Aba}	1.55 ± 0.12^{BCa}	1.31 ± 0.37^{Ca}

Means indicated by different capital letters in the same row differ significantly ($P < 0.05$). Means indicated by different lowercase letters in the same column differ significantly ($P < 0.05$). C: control, Cc: fillets with chitosan coating, O0.5: fillets immersed in chitosan coating supplemented with 0.5% of OLE, O1: fillets immersed in chitosan coating supplemented with 1% of OLE, O2: fillets immersed in chitosan coating supplemented with 2% of OLE.

The TBARS value has been widely employed as an indicator for determining the degree of lipid oxidation, which can cause off-flavor, color, and odor alterations, as well as contribute to texture deterioration in fish products (Wenjiao et al., 2013). TBARS value of rainbow trout fillets was 0.16 mg MDA/kg and increased in all samples during the storage time. TBARS values of control group and the samples immersed in chitosan solution without OLE (Cc) were higher than those of the samples incorporated with 0.5%, 1% and 2% OLE. Whereas, the value of samples immersed in chitosan solution without OLE (Cc) showed slight lower values compared with control. Chitosan coatings have been shown to prevent lipid oxidation in herring and Atlantic cod (Jeon et al., 2002).

Chitosan's antioxidant and oxygen barrier characteristics may have played a role in lipid oxidation management in pink salmon fillets. Varlık et al. (2007) offered 5 mg MDA/kg and 8 mg MDA/kg as maximum limits for "good grade" and "consumable level" qualification, respectively. The TBARS values of rainbow trout fillets were 2.07, 1.92, 1.80, 1.55, and 1.31 mg MDA/kg in the control, Cc, O0.5, O1 and O2 groups, respectively at the end of storage. The lowest TBARS value was reported in fillets immersed in chitosan coating incorporated with 2% OLE during storage period ($P<0.05$). Fadıloğlu and Emir Çoban (2018) studied that using chitosan with 2% sumac considerably reduced the lipid oxidation. According to present study, 2% olive leaves extract incorporation with chitosan coating can delay oxygen permeability due to olive leaves extract's antioxidant properties.

CONCLUSION

In this study, different concentration of OLE (0.5%, 1.0%, and 2.0%) was added to chitosan solution to prevent lipid oxidation of the rainbow trout fillets during refrigerated storage. All of the results of study demonstrated that addition of OLE (especially 2% concentration) to chitosan coating solution enhanced its efficiency and delayed lipid oxidation in rainbow trout fillets. In recent years, there has been a growing interest in alternate antioxidants agents for shelf life extension of fish. It is also suggested that chitosan coating combined with olive leaf extract might be utilized as a natural resource for the shelf life extension.

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Use of Natural Antioxidants in Edible Films and Coatings

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Abstract

As a result of the increasing population, food safety and quality have also been among the issues that consumers have taken into consideration in recent years, in addition to the access of people in the population to food production. For this reason, the packaging used in the past has been replaced by environmentally friendly biodegradable edible films and coatings, which improve the organoleptic properties of foods. In recent years, emphasis has been placed on the use of antimicrobial and antioxidant packaging materials, as they generally provide good protection against oxidative and physical stress. It has been determined as a result of studies that edible films and coatings with different application methods have approximately similar qualities. In this article, after providing information about edible films and coatings, it is aimed to provide information about application methods and antioxidant application in edible films and coatings.

Keywords: Edible Films, Natural Antioxidants, Food Quality, Coating

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INTRODUCTION

Food resources are decreasing due to the increasing world population. For this reason, food production has become important in meeting the food needs of the population as well as food safety (Ruchir et al., 2018). Foods can deteriorate for various reasons at various stages from production to delivery to the consumer. Different packaging is used to prevent deterioration and quality loss in products and to maintain their integrity (Uçan and Mercimek, 2013). Packaging is a practice that prevents and protects the food items placed inside from contact with the external environment and ensures that the food does not lose its property throughout the period from storage to delivery to the consumer. While food packaging used to only protect food from external physical and environmental factors, today it is used for a wide variety of purposes (Han 2000; Quintavalla and Vicini, 2002). The fact that the materials from which packaging is produced cause environmental pollution and create undesirable interactions in foods has led people to use edible packaging as an alternative to synthetic packaging. Edible films and coatings protect foods from physical, chemical and biological deterioration while also having a positive effect on the quality of the products (Uçan and Mercimek, 2013).This article aims to discuss what edible films and coatings are, application methods, and edible films and antioxidant packaging.

EDIBLE FILM

The use of edible films, which have become increasingly popular in recent years, dates back to ancient times. Edible films were first applied to prevent moisture loss that may occur during storage and transportation of products. Today, edible films produced using different biopolymers prevent food from spoiling by building a wall between food and packaging and have a positive effect on shelf life and are biodegradable (Pavlath and Orths, 2009).

The main function of edible films is to create a moisture and gas barrier between food and its packaging. While they make a positive contribution to the environment due to their biodegradable properties, they do not leave any undesirable effects on the physical appearance of the food and at the same time they are edible and non-toxic, which are some of the advantages of edible films. They contain ions that help stop additional browning reactions, while preventing lipid oxidation, loss of taste and unwanted color formation. They also serve to store valuable components for foods (antioxidants, antimicrobial substances, aroma compounds, pigments and vitamins) in the packaging. Due to the antimicrobial effect of edible films, there is a significant decrease in the development of microorganisms in foods. Today, studies on the properties of edible films continue to improve (Oğuzhan and Yangılar, 2016; Tural et al., 2017). Its disadvantages are in addition to being uneconomical, the number of materials to be applied is small, consumers have little knowledge because it is a new application, and it is usually used with different packaging material because it is consumed with food (Baldwin, 1994). Compared to other packaging films, they have many important features such as being environmentally friendly due to their easy dissolvability in nature, improving the organoleptic qualities (flavor, taste and smell) of foods, preserving foods by preventing them from losing moisture, acting as a good barrier against oxygen and preventing food from spoiling, and containing antimicrobial substances that are edible by the consumer (Işık et al., 2013). Edible films and coatings usually have various application methods and areas of use. While edible film coatings are applied directly to the surface of foods to obtain a specific appearance, edible films are the application of previously produced rolls or sheets to the surface of foods (Bourtoom, 2008; Guimaraes et al., 2018). It has been found that edible films and coatings have approximately similar properties despite different application techniques (Tavassoli-Kafrani et al., 2016).

APPLICATION METHODS of EDIBLE FILMS and COATINGS

Edible film/coating preparation technology; factors such as the selection of additives that are resistant to difficulties and have the ability to adapt to the application and the application method play an effective role on the coating thickness. Damage to the product should be prevented during the coating application. It varies according to the distinctive qualities of the foodstuff to be applied and the application materials. Dipping, spraying, pouring, painting and foaming, extrusion methods are used in the application of edible films and coatings.

Dipping Method

It is the application of coating the food after direct contact with the film solution, filtering it and providing suitable temperature and environmental conditions. This application is more suitable for food products that require the use of various coating materials or that require coating on irregular areas (Suhag et al., 2020).

It is a method based on direct contact of the food with the prepared solution for 5-30 seconds (Pavlath and Orts, 2009). In this method, the food absorbs the solution, and a film layer of the desired thickness is formed (Dhanapal et al., 2012). While its advantages include creating a smooth and even appearance on uneven surfaces and the coating material being suitable for cleaning and drying, its disadvantage is that it is difficult to coat large volumes of food (Salcı, 2021). It is the simplest application used mostly for covering fruits and vegetables (Dhanapal et al., 2012; Tural et al., 2017).

Spray Method

It is a method applied on surfaces where thin, smooth and equal coating is desired (Suhag et al., 2020). This method is usually used in dual applications such as calcium-alginate (Üstünol, 2009) and is used extensively to create a second film layer on coated foods (Polat, 2007). In the food industry, this is a traditional method used when the solution forming the coating is not too fluid (Suhag et al., 2020).

Pouring Method

It is a method of coating the food after the film solution, which is prepared by taking into account factors such as shape, thickness and size of the food to be applied, is placed on the area in an appropriate manner, spread, dried and then cooled (Suhag et al., 2020).

The pouring method can be used together with spraying and dipping methods, or it can be used alone (Polat, 2007; Gökalp, 1995; Caner, 2004; Sarıoğlu, 2005).

Painting and Foaming Method

It is applied by applying the fluid coating solution to the outside of the product, painting it and coating it after drying. This method is used when partial coating is to be done on the product or when an even and thin layer is desired (Polat, 2007).

It is a frequently used method because it is an application that provides thinner, smoother and more equal film formation compared to other methods, applied to the products by giving compressed air to the foam machine or application tank (Polat, 2007; Krochta, 1994).

Extrusion Method

It is frequently used in the formation of edible films based on starch. In the application based on the thermoplastic properties of polymers, plasticizers are added to the polymer materials in the range of 10-60% (polyethylene, glycol, sorbitol, etc.). Its advantage is that it is used more compared to the pouring method since there is no need for drying or solvent addition (Dhanapal et al., 2012).

USE of ANTIOXIDANTS in EDIBLE FILMS and COATINGS

The purpose of using packaging technology in all stages of the food supply chain, from food production to reaching the consumer, is to provide healthy and quality products to consumers (Cutter, 2006). Nowadays, the application of edible films and coatings in active packaging is a new method in food preservation. In addition to being cheap and easy to produce, environmentally compatible edible packaging materials have the potential to significantly reduce the use of synthetic materials by replacing them (Campos et al., 2011).
The development of environmental awareness, consumer awareness and demands in this direction have led the packaging industry to work on natural and recyclable packaging materials. Among biodegradable packaging materials, the use of edible films and coatings formed using biopolymers in the application of antimicrobial and antioxidant packaging has attracted much attention in the food sector in recent years, as they provide good protection against oxidative and physical stress (Cutter, 2006).

The main reasons for food spoilage are the increase in microorganisms and lipid oxidation in lipids. These lead to staling and undesirable taste in foods (Shahidi and Rubin, 1987; Guillen and Goicoechea, 2008). To prevent lipid oxidation, antioxidants are added directly to foods or methods are used to enrich edible packaging materials with antioxidants. It is necessary to determine that the limits of antioxidants added directly to food are not exceeded and that they do not pose a risk to consumers' health (Lopez-de-Dicastillo et al., 2010).

Recently, the increasing interest in natural plants and active ingredients derived from these sources has led to the addition of more natural antioxidant substances in antioxidant packaging techniques. In this regard, the application of antioxidant spices, extracts of various plants and natural color pigments has a critical role (Oussalah et al., 2004).

Antioxidants can be produced and used naturally and synthetically, but from the past to the present, artificial antioxidants such as polyphenol, organophosphate and thioester compounds have been primarily used to prolong the freshness of products in the industry. However, with the evidence that some artificial antioxidants have undesirable side effects in living beings, the application of natural antioxidant spices and natural aromatic plants in food production has become increasingly important. The phenolic compounds found in these plants cause antioxidant effects due to their properties such as eliminating free radicals, forming compounds with metal ions and preventing the formation of singlet oxygen. In parallel with this, some studies have determined that the antioxidant capacities of some of these plants and spices are higher compared to artificial antioxidants. Plants and spices, which tend to have more bioactivity due to their organoleptic properties such as taste and aroma, as well as their antimicrobial and antioxidant properties, are natural antioxidant substances that can be applied as alternatives in the food industry (Dopico-Garcia et al., 2011).

Antioxidants that can be used in the food industry can be divided into four classes as; antioxidants that form complexes with free radicals, which inhibit the initial free fatty acid radical formation by donating hydrogen from phenolic hydroxide groups due to the phenolic configuration in their phenolic or molecular structures; reducing antioxidants (oxygen binders) that eliminate the oxidative effect of oxygen by binding hydrogen atoms with oxygen and delay spoilage, and also help antioxidants and prevent color changes; chelates

(kelates, sequestrants) that play an active role under the name of synergists in stabilizing foods, although they are not antioxidants; and finally, secondary antioxidants that help antioxidants by decomposing hydrogen peroxide during lipid oxidation (Fiorentino et al., 2008).

Synthetic antioxidants most commonly used in the food industry are butylated hydroxyanisole, butylated hydroxytoluene and propylgallate (Abreu et al., 2010) however, natural antioxidants, which have been preferred in recent years, are generally produced in plants and spices (Fiorentino et al., 2008). In recent years, the demand for natural products with antioxidant effects such as tea, rosemary, thyme, cloves, blueberries, mustard and red wine has increased (Alen-Ruiz et al., 2009; Beddows et al., 2000; Bhale et al., 2007; Houhoula et al., 2004; McCarthy et al., 2001; Murphy et al., 2009; Ramos et al., 2014). Antioxidants have been produced from a variety of plants including marjoram, mustard, thyme, ginger, grape seed extract, aloe vera, sage, angelica, peony, reed, rosemary and cumin extracts (Fiorentino et al., 2008).

In recent years, there have been various studies on the use of edible films and coatings alone or in combination with antioxidant substances. A study on the physicochemical, mechanical, antioxidant and antimicrobial properties of carboxymethyl cellulose-based films with different ratios of essential oils obtained from different plants (*Santolina chamaecyparissus, Schinus molle, and Eucalyptus globulus*) (Eke, 2020). Some of the research on antioxidants produced using plants has focused on rosemary extract (Botsoglu et al., 2007; Pszczola, 2001). Another study shows that propolis extract can be used as a natural antioxidant source to provide oxidative stability in fish oil (Uçak, 2018). In a study conducted in 2020, semi-refined carrageenan-based edible films containing different concentrations of *Persicaria minor* (small water pepper) extract and 0.4% (BHA) were produced and the phenolic substance and antioxidant activity of the extract were determined, and the aim was to extend the shelf life of meatballs with the produced film. As a result, it was concluded that the application of the film containing the extract prevented lipid oxidation; at the same time, active films containing 2% extract had better mechanical properties compared to other films (Yahaya et al., 2020). There is a study on the antioxidant and antimicrobial effects of pomegranate peel extract in cold-stored trout burgers (Uçak, 2020). One of the studies examined the total antioxidant activity of 3 different concentrations of nettle (*Urtica diocia*) extract, which contains natural antioxidants, on rainbow trout (*Oncorhynchus mykiss*) fillets during storage and as a result, it was determined that nettle extracts extended the shelf life of fillets stored under aerobic conditions and prevented lipid oxidation (Hisar et al., 2008).

CONCLUSION

Today, against the increasing population and environmental pollution, it is important to protect food from production to delivery to the consumer, and to be respectful of the environment while doing this. For this purpose, antioxidant application in edible film and coating products extends the shelf life and has a positive effect on their quality. In addition, the fact that their source is made of natural polymers, they can be consumed by consumers and are degradable in nature is in harmony with the environment and leads to the reduction of environmental pollution.

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Food Value, Phytochemical Constituents and Physicochemical Properties of *Gladiolus Psittacinus* Bulb

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Abstract

The present study was designed to characterize the physicochemical properties, fatty acids and essential oils profile of *Gladiolus psittacinus* bulb. Physicochemical analyses were carried out following standard methods. Fatty acid compositions and essential oils were analysed by GC/MS. The saponification and Iodine values obtained were 165.50 mgKOH/g and 42.20 mg/g respectively. 1,8 Cineole (46.05%) dominated the essential oils, while fatty acids such as linoleic acid associated with lowering of fasting blood sugar was present in high concentration. Phosphatidylcholine 23.35 mg/100g was the most dominant phospholipid, while sitosterol 20.03 mg/100g was the highest occurring phytosterol in *Gladiolus psittacinus* bulb oil. Due to the presence of high concentration of essential fatty acids, essential oils, phytosterols and phospholipids in *Gladiolus psittacinus* bulb oil, it may be recommended as an important part of human diet, a potential medicinal food whose addition to diet will promote human well-being in the management and treatment of lipids related disorders such as atherosclerosis and cardiovascular diseases.

Keywords: Essential oils, Fatty acids, *Gladiolus psittacinus*, Phospholipids, Physicochemical properties, Phytosterols

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INTRODUCTION

Gladiolus psittacinus (Iridaccae) is an herbaceous plant commonly known as 'Maid of mist' and Baaka (Yoruba, southwestern Nigeria), belonging to Iridaceous family (Francois et al., 2013). It occurs virtually throughout the grasslands, savanna and woodlands of sub-Saharan Africa. It is the mostly distributed species of *Gladiolus*, throughout tropical Africa and into Western Arabia. Ethnomedicinally, it is used as a remedy for cold, dysentery, asthma, gonorrhea, mental disorder and intestinal parasite (Oyetayo et al., 2023). Ethanol extract of *Gladiolus psittacinus* bulb is used by traditional healers in south western Nigeria as an important recipe for the treatment of Diabetes mellitus (Karigidi et al., 2023).

Evaluation of the bulbs for phytochemical constituents revealed the presence of bioactive substances such as alkaloids, flavonoids, tannins, and saponins which have been shown to possess various antimicrobial properties (Munyemana et al., 2013). Several phenolic constituents have been identified to be responsible for myriads of bioactivities attributed to the *Gladiolus psittacinus* bulb. The bulb lowers blood glucose by releasing insulin from the residual beta cells, inhibition of glucagon, inhibition of gluconeogenesis in diabetic patients, act as an antimicrobial agent for the treatment of intestinal parasite and Gonorrhea. Oyetayo et al., (2023) reported that inclusion of *Gladiolus psittascinus* in diets of cognitive dysfunctioned experimental rats significantly decreased Acetylcholine estarase, butyrylcholine estarase and adenosine deaminase activities while Na^+/K^+ ATPase activity and Gamma-aminobutyric acid concentrations significantly increased following its use as a diet therapy for the treatment of scopolamine-induced cognitive dysfunctional rats. Thus, this study was carried out to assess the fatty acid composition, physicochemical properties and chemical composition *Gladiolus psittacinus* bulb oil.

MATERIAL AND METHOD

Sampling and sample treatment

Gladiolus psittacinus bulb were obtained from a local Market in Ado Ekiti, Ekiti State and were identified at the Herbarium of the Department of Plant Science and Biotechnology of Ekiti State University, Ado Ekiti. The bulbs were sliced and oven dried at 40^0C for 6 hours, the dried sample was powdered in a warring laboratory blender and stored in an air tight container at room temperature prior analysis.

Extraction of *Gladiolus psittacinus* bulb Oil

The *Gladiolus psittacinus* bulb oil was extracted using the soxhlet extraction procedure (Harwood and Moody, 1989). The bulb powder was packed into filter papers and tied neatly. They were placed in a thimble which was suspended above a round bottom flask containing the extraction solvent (n-Hexane) and below a condenser. The flask was heated to 50^0C. The soxhlet evaporated and moved up into the condenser where it was converted back to liquid which trickled into the extraction chamber through the sample and back into the boiling solvent. After 6hrs of this cycle, the boiling flask content was removed and placed in the rotary evaporator which separated the *Gladiolus psittacinus* bulb oil from the extracting solvent. The oil was afterwards collected into a clean bottle.

Physicochemical Analysis

The acid, saponification, iodine and refractive index values of the various oil samples were determined by AOCS (2005).

Determination of Iodine Value

Fat solution of 20g of *Gladiolus psittacinus* bulb oil was dissolved in 100 ml of chloroform. 10ml of the oil solution was pipetted into a stopper bottle and 25ml of Iodine monochloride was added. The stopper bottle was shaken thoroughly and placed in the dark for one hour. A blank solution was prepared with the oil solution replaced with 10ml of water.

After an hour, the stopper bottles were rinsed with about 50ml of water and 10ml of potassium Iodide were added. The resulting solution was titrated with standard thiosulphate. When the solution turned pale straw, 1ml of starch solution was added and the titration continued until blue colouration formed with the starch solution disappeared. The titre values for the test and blank were used to calculate the iodine value

$$\text{Iodine Value} = (\text{Blank} - \text{Test}) \text{ X } 6.35 \quad (1)$$

Determination of Acid Value

About 10g of *Gladiolus psittacinus* bulb oil was weighed into a beaker. Fifty ml of fat solvent was pipetted into the oil and 1ml of phenolphathalein solution was added and mixed thoroughly. The solution was titrated with 0.1M of potassium hydroxide until faint pink colour persisted for 20 seconds. The titration was done in duplicate and the acid value was calculated.

$$\text{Acid Value} = (\text{titre value X } 5.6)/10\text{g (weight of the sample)} \quad (2)$$

Determination of Saponification Value

About 5g of *Gladiolus psittacinus* bulb oil was placed in a conical flask and 50ml 0.5M of alcoholic KOH was added to the oil. A blank was prepared by dispensing 50ml of 0.5M alcoholic KOH with blank solution into another conical flask. A reflux condenser was connected to each flask and was boiled for an hour. On cooling, the condenser was rinsed with little distilled water and was removed. One ml of phenolphthalein indicator was added into each flask and titrated against 0.5ml HCl until the pink colour disappeared. The titre value was taken and the saponification value was calculated thus

$$\text{Saponification value (mg/g)} = (\text{Blank titre value} - \text{sample titre value x } 28.05)/\text{Weight of the sample} \quad (3)$$

Phospholipids Analysis

About 0.01g of *Gladiolus psittacinus* bulb oil was added to test tubes. Any remaining solvent was removed by passing a stream of nitrogen gas over the oil. Then 0.40ml of chloroform was added, followed by the addition of 0.10ml of chromogenic solution. The tube was heated to 100^0 C on a water bath for 1min 20 seconds, cooled to room temperature, 4ml of hexane was added and the solvent and aqueous layers the hexane were recovered and concentrated to 1.0ml for analysis. Analysis was performed using gas chromatograph with a polar capillary column (30m x 0.25mm x 0.2micrometer). The oven programme was initially at 50^0C ramping at 10^0C/ min for 20min, held for 4min, a second ramping at 15^0C/ min for 4mins and held for 5minutes. The injection temperature was 250^0C, and the detector temperature 320^0C. As previously described, a split injection type was used having a split ratio of 20:1. Peaks were identified by comparison with known standards (Raheja et al., 1973).

Phytosterols Analysis

An aliquot of *Gladiolus psittacinus* bulb oil was added to screw-capped test tubes. The sample was saponified at 95^0C for 30mins, using 3ml of 10% KOH in ethanol, to which 0.20ml of benzene was added and 2ml of hexane was used in extraction of the non-saponifiable materials. Three extractions, each with 2ml of hexane, were carried out for 1hr, 30min and 30min respectively, to achieve complete extraction of the phytosterols. Hexane was concentrated to 1ml of gas for chromatographic analysis (AOAC, 1997).

Essential Oils Analysis

Essential oils extraction was carried out following the modified method of Jarubol (2009). About100g of pulverized sample was weighed into 1000ml round bottom flask. The flask with weighed sample, condenser and other gadgets were connected to complete the hydro-distillation arrangement using Clevenger-type apparatus. The crushed sample in the flask was entirely covered with deionized water suspension and placed on the heating mantle. The water was allowed to boil in the flask and the essential oil carried over to the condenser along with the steam. The essential oil and steam were separated below the condenser through a separator. It was then dried over anhydrous sodium sulphate and stored in a 2ml sealed Agilent vial protected from light at 4^0C before chromatographic analysis. The oils were analyzed on an HP6890 GC, powered by HP chemstation Rev.A09.0 (1206) software. Flame ionization detector (FID) fitted with fused silica capillary column with dimension 30m x 0.23mm x 0.25micrometer was used. The oven temperature was programmed from 40^0 – 200^0C at 5^0C / min and run at 200^0C for two minutes. Split injection temperature of 150^0C with split ratio 20:1 was used. The detector temperature was 300^0C and the carrier gas was hydrogen at flow rate 1.0ml/minute. Hydrogen pressure was 22psi with compressed air of 28psi.

Fatty Acids Analysis

Crude oil of *Gladiolus psittacinus* bulb oil was made water free by filtering through anhydrous sodium sulphate salt. Hexane was removed from the oil per hexane mixture using rotator evaporator. Fatty acid profile, saturated, mono and poly unsaturated analysis were carried out following the modified AOAC (1997) methods. About 50mg of *Gladiolus psittacinus* bulb oil was saponified for 5mins at 95^0C with 3.4ml of the 0.5M KOH in dry methanol. The mixture was neutralized by using 0.7M HCl. About 3ml of the 14% boron triflouride in methanol was added. The mixture was heated for 5mins at 90^0C to achieve the complete methylation process. The fatty acid methyl esters were thrice extracted from the mixture with redistilled n-hexane.The fatty acid content was concentrated to 1ml for the gas chromatography analysis and 1ml was injected into the injection port of the GC equipment. Flame ionization detector (FID) fitted with fused silica capillary column with dimension 30m x 0.23mm x 0.25micrometer was used. The oven temperature was programmed from 40^0 – 200^0C at 5^0C/ min and run at 200^0C for two minutes. Split injection temperature of 150^0C with split ratio 20:1. The detector temperature was 300^0C and the carrier gas was hydrogen at flow rate 1.0ml / min.

RESULTS AND DISCUSSION

Table 1 shows the physiochemical properties of *Gladiolus psittacinus* bulb oil. The bulb oil is a rich source of plant oil with concentration as high as 21.6%. This concentration was relatively high compared with those obtained for various plant foods such as the bulb (0.08-0.03%) and aerial part (0.16-0.25%) of *Allium sativum* (Nazzaro et al., 2022).Acid value, an indication of the concentration of free fatty acids present in oils is an important parameter to assess food quality. The higher the acid value, the lower the possibility of oil to be used for cooking. High acid value shows that the oil triglycerides are converted to fatty acids and glycerol which can lead to oil rancidity. The acid value (mg/KOH/g) of the *Gladiolus psittacinus* bulb oil, 3.0 mg/KOH/g is lower than that of Neem seed oil (Hamadou et al., 2020). The low concentration of fatty acids in the bulb oil is an indication that the oil is predominately composed of triacylglycerol. Iodine value is a measure of degree of unsaturation of fat. The Iodine value of *Gladiolus psittacinus* bulb oil was 42.20 mg/g indicating the oil as a non-drying oil which could be useful as a lubricant. The low Iodine value of *Gladiolus psittacinus* bulb oil also suggests greater storage ability of the oil. Saponification value is another important parameter used for the characterization and assessment of the quality of edible fats and oils. Furthermore, it gives information about the average molecular weight of all constituting fatty acids. The higher the saponification value, the lower the molecular weight of all fatty acids. Saponification value of *Gladiolus psittacinus* bulb oil, 195 mg/KOH/g compared favourably to Neem seed oil of 199.81 mg/KOH/g (Hamadou et al., 2020).

Table 2 shows the phospholipids composition (mg/100g) of *Gladiolus psittacinus* bulb oil. Phosphatidylcholine (lecithin) the most abundant phospholipid in *Gladiolus psittacinus* bulb oil (23.35 mg/100g) is a key building block of membrane bilayers. It is also the principal phospholipid circulating in the plasma, where it is an integral component of lipoproteins, especially the HDL. It has been reported to enhance neuronal differentiation and lessen neuronal alterations caused by inflammation (Magaquian et al., 2021). Up to 30 grams of lecithin per day is considered safe if taken as a supplement. However, higher doses may result in anorexia, sweating, increased salivation, hepatitis and gastrointestinal distress, such as nausea and diarrhea (Annonymous, 2024). Phosphatidylserine was the second most abundant phospholipids in *Gladiolus psittacinus* bulb oil with concentration as high as 15.75 mg/100g, phosphatidylserine aids in the transmitting messages between brain nerve cells. It helps in blood clotting, coats and shields brain cells, and may be crucial for maintaining memory and aiding in neurotransmitter release, synaptic transmission, and neural signaling. Phosphatidylserine forms part of the cerebral cortex and aids cognitive functions (Eun et al., 2022). The consumption of phosphatidylserine may reduce the risk of cognitive dysfunction, enhancement of mood in young people during mental stress.

Gladiolus psittacinus bulb oil contains 7.81 mg/100g of phosphatidylinositol. It is a minor component in the cytosolic site of eukaryotic cell membrane. Inositol can be phosphorylated to form phosphatidylinositol phosphate (PIP), Phosphatidylinositol biphosphate (PIP_2) and phosphatidylinositol triphosphate (PIP_3) which are collectively called phosphoinositides. They control a wide range of biological processes, including vesicular endocytosis, membrane identification and fusion of membrane vesicles (Jill et al., 2022).

PIP_2, a precursor for PIP_3 synthesis, has been reported to play a major role in cytoskeletal linkage, regulation of ion channels, and intracellular trafficking. (Mandal, 2020). Phosphatidylethanolamine (Cephaline) with a concentration of 6.64 mg/100g in *Gladiolus psittacinus* bulb oil is found in all living cells, although in human physiology it is found particularly in nervous tissue such as the white grey matter.

Clinically, significant reduction in LDL-cholesterol values have been linked to diets enriched with plant sterols, and its supplementation into food is a treatment strategy to manage familial hypercholesterolemia (Barkas et al., 2023). In view of this, phytosterols (mg/100g) composition of *Gladiolus psittacinus* bulb oil were analyzed as shown on table 3. The most abundant phytosterols in *Gladiolus psittacinus* bulb oil, sitosterol, showed a concentration of 21.06 mg/100g. Phytosterols compete with cholesterol for absorption in the small intestine. When consumed, they occupy the same micelle sites as cholesterol, reducing the amount of cholesterol that can be absorbed into the bloodstream. This, in turn, leads to lower LDL (bad) cholesterol levels, a major factor in the development of coronary heart diseases. Campesterol, (12.75mg/100g) was the second most abundant phytosterol in *Gladiolus psittacinus* bulb oil which is comparable with the previous reports of 11.00 mg/100g by Li et al., (2022) in *Arabidopsis thaliana* plant. Campsterol (12.75) has shown promise in modulating inflammatory responses. Sarwat et al., (2024) demonstrated that Campesterol derivatives improved nociception behavior and exhibited anti-inflammatory and antioxidant effects by reducing the thickness of paws and inhibiting the release of inflammatory mediators such as IL-1β and TNF-α.

Table 4 shows the fatty acid profile of *Gladiolus psittacinus* bulb oil. The dominant fatty acid in *Gladiolus psittacinus* bulb was linoleic acid (41.34%). This concentration is considered high compared to 31.47% reported for the seed flour of *Luffa cylindrica* (Oyetayo and Ojo, 2012). Linoleic is a polyunsaturated fatty acid which is beneficial to health High linoleic concentration has been associated with a low risk of developing coronary heart diseases. Oleic acid (20.15%) was the next high occurring fatty acid in bulb oil. Both fatty acids are unsaturated which exhibit fewer tendencies towards the development of heart related disorders. The oleic/linoleic acid ratio (O/L) largely influence oxidative stability and hence shelf life (Sahin, *et al.,* 2022). O/L ratio of 1.00 and above is associated with high stability and potentiality of oil for deep frying. The O/L ratio of *Gladiolus psittacinus* bulb oil, 0.65 (approximately 1.0) shows its potential as a stable oil. Oleic acid influences membrane fluidity and integrity. Its incorporation into membranes affects cellular signaling and various cellular functions and plays a role in regulating cell proliferation and differentiation, particularly in skin health and wound healing (Xu *et al.,* 2015). *Gladiolus psittacinus* bulb oil was found to contain relatively low concentration of saturated fatty acid except for palmitic acid (21.68%) which is the most concentrated saturated fatty acid compared with 25.48% fatty acid composition of the seeds of *Costus afer* (Chioma *et al.,* 2020). Margaric (0.01%) and Behenic acid (0.08±%) concentrations were low. Behenic acid-rich structured lipids have demonstrated promise in the context of obesity and metabolic health for reducing weight gain and enhancing glucose and lipid balance (Reginaldo *et al.,* 2020). The total unsaturated fatty acid (69.90%) of *Gladiolus psittacinus* bulb oil was higher than the saturated fatty acid concentration (30.10%). Since diets with higher concentration of plant based unsaturated fats have been established to reduce the risk of cardiovascular diseases, *Gladiolus psittacinus* bulb presents a potential source of healthy oil in the prevention of cardiovascular disorders.

Essential oils are secondary metabolites composed of mixture of different compounds including terpenic hydrocarbons like ketones, epoxides, aldehydes and esters (Stephane and Jules 2020). They give aroma and flavor to plants and are synthesized to attract pollinators, disperse seeds, and protect against pests and predators (Mugao *et al.*, 2020). The aroma is frequently employed in cosmetics and aromatherapy fields (Agrawal *et al.*, 2024). They are also popular as food additives due to their antimicrobial and antioxidant capabilities (Manso *et al.* 2014). The composition of essential oils isolated by the hydro distillation of *Gladiolus psittacinus* bulb are presented in table 5. A total of 19 essential oils were identified from *Gladiolus psittacinus* bulb. The most abundant essential oil was 1,8-Cineole (46.05%). Also referred to as eucalyptol, its concentration is comparable to 54.29% earlier reported for *E. maculate* leaf (Almas *et al.*, 2021). It has demonstrated a wide range of pharmacological qualities, such as anti-inflammatory and antioxidant effects, primarily through the regulation of NF-κB and Nrf2 and has been used in treatment of cardiovascular and respiratory disorders (Cai *et al.*, 2021). Beta-pinene, the second most abundant essential oil in *Gladiolus psittacinus* bulb oil (15.13%) compares favorably with 12.79% obtained for *Citrus medica* earlier reported (Weixuan *et al.*, 2023). *Gladiolus psittacinus* bulb oil contains limonene a cyclic terpene with an orange fruit-like aroma, a useful fragrance applicable in cosmetics. It has been reported to posses' effective anti-inflammatory activity in the prevention of respiratory system injuries (Santana *et al.*, 2020). Linalool also reported for its anti-inflammatory activity (Kim *et al.*, 2019) was the third highest concentrating essential oil present in the bulb oil.

Table 1. Fat Composition and Physicochemical of *Gladiolus psittacinus* bulb

Parameter	Value
% Crude fat	21.60
Acid value (MgKOH/g)	3.00
Iodine Value (Mg/g)	42.20
Saponification value (MgKOH/g)	195.00
Refractive index@40^0C	1.49

Table 2. Phospholipids Composition (mg/100g) of *Gladiolus psittacinus* bulb oil

Phospholipids	Concentration (mg/100g)
Phosphatidylethanolamine	5.84
Phosphatidylcholine	23.35
Phosphatidylserine	15.75
Lysophosphatidylcholine	2.42
Phosphatidylinositol	7.81
Phosphatidic acid	4.46

Table 3. Phytosterols Composition (mg/100g) of *Gladiolus psittacinus* bulb oil

Phytosterols	Concentration (mg/100g)
Campestrol	12.74
Stigmasterol	6.66
Savenasterol	2.23
Sitosterol	20.03

Table 4. Fatty Acids Composition % of *Gladiolus psittacinus* bulb oil

Fatty Acid	Concentration (%)
Palmitic acid	21.68
Margaric acid	0.01
Stearic acid	7.64
Arachidic acid	0.51
Behenic acid	0.08
Lignoceric acid	0.18
Total saturated fatty acid	30.10
Monounsaturated fatty acids	
Palmitoleic acid	0.10
Oleic acid	20.15
Erucic acid	0.10
Total monounsaturated fatty acid	20.35
Polyunsaturated fatty acid	
Linoleic acid	46.75
Arachidonic acid	0.05
Linolenic acid	2.76
Total polyunsaturated fatty acid	49.55
TOTAL UNSATURATED FATS (MUFA + PUFA)	69.90
Oleic/linoleic acid ratio	0.43

Table 5. Essential oil Composition (%) of *Gladiolus psittacinus* bulb oil

Essential oils	Concentration (%)
α -pienene	4.39
β-pinene	15.13
Limonene	0.54
Cis ocimene	1.64
Pinene-2-ol	1.20
α -troujere	0.70
ɣ-terpinene	0.05
Geranial	0.01
Linalool	6.27
1,8cinole	46.05
Citronellal	0.04
α –terpineol	11.74
Terpinen-4-ol	3.12
Citronellol	0.04
α--terpinenly acetate	4.34
Neryl acetate	0.02
Geranyl acetate	4.65
Humulene α- caryophylene	0.04

CONCLUSION

The present investigation reveals *Gladiolus psittacinus* bulb oil as a novel source of beneficial unsaturated fatty acids, phospholipids and essential oils. The bulb oil is rich in fatty acids such as linoleic and oleic acids which are unsaturated fats beneficial for lowering blood cholesterol levels. The phospholipids contain high levels of phosphatidylcholine and phosphatidylserine and the essential oils are rich in 1,8 Cineole and beta-pinene which have high nutritional, pharmacological and health benefits and as such, dietary supplementation and consumption of *Gladiolus psittacinus* bulb oil could be beneficial to human health. However, further studies to evaluate the possible *in vivo* toxicological potentials of the oil is expedient.

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