

Effect of Berberis vulgaris L. Extract on Beef Patties Quality Parameters

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Research Article

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Abstract

The effects of adding *Berberis vulgaris* L. fruit extract to beef patties (patties) on physicochemical, sensory, texture and safety features were investigated.

The addition of the extract did not cause a significant change in the approximate composition (moisture and ash) of the patties. It had a significant effect on the pH value in all groups of raw and cooked patties ($P < 0.01$). Initially, it had a significant effect on the TBARS value in all groups ($P < 0.05$), while there was no significant difference in TBARS values after cooking ($p > 0.05$). While no significant difference was observed for the color values, cooking caused a fall in L^* , a^* and b^* values. Cooking yield had a significant effect in all groups ($P < 0.01$). The use of *Berberis* extract in patties reduced the cooking yield. The addition of the extract did not change the sensory features of the patties by a significant degree. Additionally, texture analysis showed very significant effects of hardness (N), gumminess (N) and chewiness (mJ) values in all groups ($P < 0.01$). The findings indicate that the extract does not significantly alter the patties' properties but reduces lipid oxidation and enhances textural attributes. This study supports the potential use of *Berberis vulgaris* L. extract as a natural additive to improve the quality of beef patties.

Introduction

Adequate and balanced nutrition is one of the basic conditions for individuals in society to live healthily, develop in economic and social terms and increase welfare levels [1]. From this perspective, protein is very important and meat is the best source of animal protein [2]. These products are perfect food material in terms of the protein they contain being rich in essential amino acids and containing low proportions of carbohydrates [3]. The structure of meat and meat products also includes high amounts of iron, zinc, selenium, niacin, vitamins A, B6 and B12 and essential fat acids [4].

The most important sensory quality criteria for consumers of food are appearance, color, texture and flavor. The basic cause of degradation occurring in these quality criteria of meat and meat products and one of the most important changes limiting shelf life is lipid oxidation [5]. The meat industry uses thermal and non-thermal food preservation methods to remove these risks and satisfy consumers [6]. Among these methods, food additive materials and curing ingredients have been used for many years [7]. Additionally, the use of functional and natural additive materials in the formulations of meat products is one of the topics receiving the most focus [8]. An example is the addition of plant parts rich in terms of flavonoids, like seeds, fruit skin or rind and flowers, raw or as extracts in recipes to increase the antioxidant capacity of meat [9].

Beef patties are a traditional tasty snack with rich nutritional value and unrivaled flavor. Additionally, the quality of beef patties is easily affected by several factors like processing, storage and preservation, limiting their competitive place in the market. As a result, it is important to pay attention to every step during the processing of beef patties [10].

The shelf life of beef patties, offered to the market raw or with pre-cooking processes applied, is limited due to a variety of factors (appropriate medium for microorganisms, suitable pH, high water activity, presence of unsaturated fat acids, etc.) [5]. To secure the quality of the product and remove risks that consumers might encounter during the production of these products, a variety of spices, natural plants and additive materials are used [9, 11].

Diverse studies show that synthetic or natural preservatives can be used to control microbial degradation and lipid peroxidation [12, 13]. However, as consumers worry about the toxic effects of synthetic antioxidants, the use of natural antioxidants in foods has attracted attention in the present day [12].

In recent years, the use of natural antioxidants to increase the oxidative stability of meat products has rapidly increased in research [9, 14]. Studies reported that several herbal resources have antioxidant and antimicrobial effect (e.g., grape, date, broccoli, potatoes, thyme, curry, squash, tea, and nettles) [15].

Berberis vulgaris L., with a red color and sour flavor, belongs to the *Berberis* genus of the *Berberidaceae* family [16]. In the food industry, it is used in the production of jam, sweets and wine, as well as tea [17].

Berberis (*Berberis* L.) species are commonly used for nutrition, medicine and homeopathy [18]. The fruit of *Berberis vulgaris* L. is used for kidney, urinary and stomach disorders, liver disease, bronchitis disorders and as a stimulant for the circulation system [19].

Additionally, *Berberis vulgaris* L. fruit contains significant levels of antioxidant activity and was identified in studies to be beneficial in terms of health [20, 16].

In the literature, there is no study about the use of *Berberis vulgaris* L. fruit extract for the production of beef patties. In this study, firstly production of a functional product was completed. Additionally, the effects of the extract on the physicochemical, sensory, textural and safety features of the beef patties were assessed.

Material-Method

In the research, minced beef and beef fat obtained from a local butcher were used. Additionally, *B. vulgaris* L. (barberry) fruit was collected from local gardens in Bayburt province. The minced beef and beef fat to be used in the study were brought to Bayburt University Aydıntepe Vocational School Department of Food Processing Laboratory under suitable conditions and stored at 4°C until use as research material.

Preparation of Fruit Extract

Of the fruit, 100 g was taken and dried in an oven. Then the dried fruit was ground in porcelain mortars until they reached an appropriate grain size. Then, 100 mL ethanol (80%) was added to 10 g of sample and the mixture was left for extraction for 48 hours in a water bath with temperature fixed below 40°C.

Then the extract was filtered and underwent evaporation in an evaporator. The obtained extract was dried in a lyophilizer and the fruit extract was prepared.

Antioxidant Evaluations and Overall Phenolic Substance Content

The study employed three fundamental analysis methods to evaluate the antioxidant properties and total phenolic content of plant extracts. Firstly, the DPPH analysis determined the extract's capacity to absorb DPPH radicals, expressing antioxidant activity as Trolox equivalent (mg/g) based on the optical density measured at 517 nm [21]. Similarly, the ABTS analysis evaluated the extract's ability to reduce ABTS substrate, correlating the absorbance change at 734 nm with Trolox equivalent (mg/g) [22]. Additionally, the Folin–Ciocalteu phenol analysis determined the total phenolic components of the extract, presenting the results in terms of Gallic acid equivalent (mg/g) [23]. These analysis methods comprehensively assessed different aspects, including antioxidant capacity, radical scavenging ability, and total phenolic content, providing a detailed evaluation of the biological activity of plant extracts.

Patties production and sampling

Patties production was used minced beef and beef fat at + 4°C. The fat proportion was set to 20% of minced beef and a homogeneous mixture was obtained. The lyophilized extract was added to the mixture at rates of 0.1%, 0.2% and 0.4%. The control group had no extract added. All groups had 1.5% salt added. The prepared mixtures were kneaded until homogeneous. The patties were shaped and the prepared patties were left to rest at 4°C for 1 day.

Physicochemical Analyses

Raw samples obtained from patties in each group had moisture [24], pH [25], ash [24], color and thiobarbituric acid reactive substances (TBARS) [26] analyses completed. Cooked patties had pH, TBARS, color, sensory analysis after microbiological analyses and textural analysis completed. Additionally, the cooking yield of the patties was identified.

Color values (L*, a*, b*) of the samples were determined using a Chroma Meter (CR-200, Minolta Co, Osaka, Japan) colorimeter. Color measurements were assessed according to the criteria determined by the Commission Internationale de l'Eclairage based on three-dimensional color measurements. Accordingly, color intensities are shown by L*; L*=0, black; L*=100 white (darkness/brightness); a*; +a*=red, -a*=green and b*; +b*=yellow, b*=blue. Before use, the device was calibrated with a standard calibration scale.

The following equation was used to identify cooking yield [27].

Cooking yield = patties weight after cooking (g) / patties weight before cooking (g) * 100

Total Aerobic Mesophilic Bacterial Count (TAMB)

Seeding was performed with the plate count agar (PCA, Merck) spreading method and samples were incubated under aerobic conditions for 2 days at 30°C in Petri dishes. Count results were determined as log cfu/g at the end of incubation.

Enterobacteriaceae Count

For detection of Enterobacteriaceae counts, seeding was performed with the violet red bile dextrose (VRBD, Merck) agar spreading method. Plates were incubated under anaerobic conditions for 2 days at 30°C. Red colonies larger than 1 mm were counted after incubation and are given as log cfu/g.

Sensory Analysis

For analysis in sensory terms, patties were cooked for 12 minutes by turning on a heating plate at 170–180°C until the internal temperature reached 72°C. Sensory assessments of ready-to-consume cooked patties samples were performed by panelists using the hedonic scale (1–9) given below [27].

Texture Profile Analysis

Texture analysis was completed with a device (CT3, Brookfield Engineering Laboratories, USA). Cylindrical samples taken from the patties (20 mm diameter, 10 mm height) underwent TPA analysis (conditions: pretest velocity 1 mm/g, test velocity and post-test velocity 2 mm/g, 5 s between first and second compression and compression rate 50%) at room temperature with two compression cycles using a 50 mm cylindrical probe. Textural parameters were calculated from the obtained force-time curves (hardness, adhesiveness, cohesiveness, springiness, chewiness, gumminess and resilience) [29].

Statistical Analyses

In the study, four different extract proportions (control, 0.1%, 0.2% and 0.4% fruit extract) were taken as factors and the research was arranged and completed with 2 repeats according to a random full block trial plan. The results obtained underwent variance analysis and means for the significant main variation sources were compared with the Duncan multiple comparison test (SPSS 20.0).

Results and Discussion

Antioxidants can alleviate lipid peroxidation by scavenging free radicals, interrupting chain reactions, breaking down peroxides, lowering localized oxygen concentrations, and attaching to chain-initiating catalysts like metal ions [30]. Antioxidants provide effective protection against diseases associated with oxidative stress, such as cancer, obesity, coronary heart disease, type 2 diabetes, cataracts, and hypertension. Therefore, consuming antioxidant-rich fruits, vegetables, and unprocessed staple foods is crucial [31]. The antioxidant potential of *B. vulgaris* L. fruit extract was observed to be 25.450 ± 0.354 mg TE/g for DPPH and 42.420 ± 2.588 mg TE/g for ABTS in the present study (Fig. 1). Importantly, in various conducted studies, the *B. vulgaris* L. extract consistently demonstrated significant antioxidant activity [32, 33].

Figure 1. Antioxidant activity and total phenolic content of fruits. The columns in the table represent the mean of three replicates, and the vertical bars indicate the standard error of the mean. Values marked with * within each row are significantly different according to ANOVA ($p < 0.05$).

The barberry fruit is recognized as a beneficial addition frequently employed in diverse food products, owing to its abundant levels of phenolic compounds (anthocyanins) and ascorbic acid

[34]. In the study, the polyphenol contents of *B. vulgaris* L. fruit was determined as 71.090 ± 0.283 mg GAE/g (Table 1). In the literature, different results were obtained in terms of total phenolic content depending on the geographical regions where barberry fruits were harvested, environmental and climatic conditions, growing season, soil type, storage and processing conditions [33]. According to the statistical results, the total phenolic content of fruit showed a significant impact ($p < 0.05$).

Table 1
Moisture, pH, Ash, Color, TBARS Value, and cooking yield in raw and cooked beef patties (Mean $\pm$ SD)

		Ratio (%)				
		0	0,1	0,2	0,4	Sig
R	Moisture (%)	71,19 $\pm$ 9,20a	63,13 $\pm$ 0,47a	63,73 $\pm$ 0,48a	64,94 $\pm$ 0,35a	ns
C	Moisture (%)	55,21 $\pm$ 0,51a	50,91 $\pm$ 0,65a	54,90 $\pm$ 4,99a	53,41 $\pm$ 0,79a	ns
R	pH	5,68 $\pm$ 0,01c	5,62 $\pm$ 0,01c	5,48 $\pm$ 0,05b	5,32 $\pm$ 0,06a	**
C	pH	5,91 $\pm$ 0,01d	5,83 $\pm$ 0,02c	5,71 $\pm$ 0,01b	5,54 $\pm$ 0,02a	**
R	Ash (%)	2,22 $\pm$ 0,34a	1,29 $\pm$ 0,55a	2,61 $\pm$ 0,47a	1,94 $\pm$ 0,59a	ns
C	Ash (%)	2,83 $\pm$ 0,18a	2,76 $\pm$ 0,11a	2,98 $\pm$ 0,07a	2,75 $\pm$ 0,06a	ns
R	L*	65,46 $\pm$ 4,31b	59,96 $\pm$ 5,59ab	54,68 $\pm$ 5,86a	60,37 $\pm$ 3,16ab	ns
C	L*	55,95 $\pm$ 1,77a	50,44 $\pm$ 7,56a	49,06 $\pm$ 1,88a	51,88 $\pm$ 3,95a	ns
R	a*	25,61 $\pm$ 1,92a	26,32 $\pm$ 6,26a	25,87 $\pm$ 4,95a	29,18 $\pm$ 0,65a	ns
C	a*	23,09 $\pm$ 2,16b	17,46 $\pm$ 2,02a	17,49 $\pm$ 0,96a	15,64 $\pm$ 3,77a	ns
R	b*	13,68 $\pm$ 0,68a	13,34 $\pm$ 2,24a	12,39 $\pm$ 1,72a	12,61 $\pm$ 2,79a	ns
C	b*	9,40 $\pm$ 1,38a	9,02 $\pm$ 1,58a	8,89 $\pm$ 1,79a	8,89 $\pm$ 2,74a	ns
R	TBARS (mg MDA/kg)	1,95 $\pm$ 0,04b	1,72 $\pm$ 0,16b	1,53 $\pm$ 0,08a	1,63 $\pm$ 0,01a	**
C	TBARS (mg MDA/kg)	2,29 $\pm$ 0,33a	1,72 $\pm$ 0,36a	2,01 $\pm$ 0,21a	1,86 $\pm$ 0,14a	ns
	Cooking Yield (%)	75,72 $\pm$ 1,22c	70,17 $\pm$ 0,33b	68,87 $\pm$ 0,72ab	67,41 $\pm$ 0,57a	**
Sig (Significance), R (Raw), C (Cooked), SD (Standard Deviation), ** p < 0.01, * p < 0.05 (Significance Levels), ns (Non-significant for p > 0.05), and different letters in the same column (a-c) indicating significant differences (p < 0.05) are utilized.						

The physicochemical analysis results for the beef patties are given in Table 1.

As stated in the literature, the addition of the extract did not lead to a significant alteration in the approximate composition of the patties, particularly in terms of moisture and ash content [5, 35]. These findings indicate that the impact of the extract on the initial composition of the patties is limited, while the observed loss of moisture during the cooking of patties aligns with a common outcome observed in meat and meat product cooking processes [36, 37].

In this context, it is suggested that the extract may influence the moisture retention capacity of the patties during the cooking process. Consistent with the hypothesis that the addition of the extract might have an augmenting effect on moisture loss, particularly during cooking, this situation supports the dynamic changes in composition during the cooking process. These findings demonstrate that the addition of the extract maintains the stability of the composition of the patties while inducing changes in the moisture content during the cooking process.

The pH values of raw patties exhibit a significant impact across all experimental groups ($P < 0.01$), highlighting that the addition of the extract significantly lowered the pH levels. This decline can be attributed to the naturally low pH value (2.85) of *Berberis vulgaris*. The observed substantial effect of the extract on the acidity of raw patties underscores a noteworthy alteration in the pH profile induced by the botanical extract. During the cooking process, a pronounced effect on pH is evident in all groups ($P < 0.01$), indicating a complex interaction with factors such as the initial pH of raw materials and buffering capacity [38]. Traditionally, an increase in pH is expected during the cooking of meat [39, 40], a trend supported by similar findings in the literature [41, 11]. The low pH of *Berberis vulgaris* and its contribution to the acidity profile of both raw and cooked patties highlight significant factors influencing overall acidity control in the product. These findings contribute valuable insights into the distinct impact of the botanical extract on the chemical attributes of the patties.

The TBARS values of raw patties exhibited a significant impact in all groups ($P < 0.05$). The presence of antioxidants and phenolic components in the extract reduced lipid oxidation and free radical formation, thereby enhancing the product's antioxidant capacity. An increase in the extract proportion resulted in lower TBARS values compared to the control group. These findings align with studies conducted by Ahn and Grün [42], Mahapatra et al. [43], and Erdoğan and Özdestan-Ocak [35]. During the cooking process, no significant difference was observed between TBARS values ($p > 0.05$). This suggests that the cooking procedure did not influence TBARS values. These results affirm that the low TBARS values in raw patties can be attributed to the antioxidant properties of the extract, effectively mitigating lipid oxidation and free radical formation. In the literature, various studies support the notion that plant extracts play a crucial role in controlling lipid oxidation in meat products. Ahn and Grün [42] highlighted that plant extracts enhance antioxidant activity and extend the shelf life of meat products. Another study by Mahapatra et al. [43] demonstrated that plant extracts inhibit lipid oxidation and improve product quality. Similarly, research conducted by Erdoğan and Özdestan-Ocak [35] reported that plant extracts provide antioxidant efficacy in meat products, reducing lipid oxidation. Collectively, these findings underscore the significant potential of plant extracts in enhancing the quality of raw patties.

While no statistically significant difference was observed in color values, the cooking process led to decreases in L*, a*, and b* values. These color changes are likely attributable to factors such as an increase in metmyoglobin concentration or myoglobin denaturation. In this context, the findings align with similar results from Kirkyol and Akköse [11], supporting the impact of decreases in color values during the cooking process on meat pigments. Given that color changes often influence the visual and flavor characteristics of a product, these findings underscore the importance of understanding the physical and chemical transformations occurring during the cooking process. Therefore, the scientific insights gained from this study contribute to a better understanding of the potential effects of color changes in meat during cooking on product quality.

The cooking of meat is a crucial step for both flavor enhancement and ensuring product safety. Microbiological analyses play a pivotal role in evaluating the microbiological quality and safety of the product, aligning with product specifications or legally applicable standards [29]. In this study, microbiological analyses indicated that the Total Aerobic Mesophilic Bacteria (TAMB) and Enterobacteriaceae counts were below the detectable limit ($< 2 \log \text{ cfu/g}$) after the cooking process. The microbiological results underscore the notion that the cooking process enhances microbiological safety, contributing significantly to the overall safety of the product. The use of extract is believed to potentially contribute to maintaining microbiological stability. This aspect holds particular importance for the product's shelf life and, consequently, consumer safety. However, a more detailed analysis is warranted to elucidate the specific effects of the extract on microbiological stability. Further investigation into how the extract may exert antimicrobial effects and its impact on microbial growth would provide valuable insights. Such in-depth analyses can inform specific strategies to maintain and improve the microbiological quality of the product.

Cooking yield stands out as a pivotal test for predicting the behavior of meat industry products during the cooking process, considering non-meat compounds or other contributing factors [44]. Significant effects of cooking yield were observed across all groups in this study ($P < 0.01$). The incorporation of Berberis extract into the patties resulted in a notable reduction in cooking yield. This outcome is presumed to stem from excessive fat and moisture separation during the cooking process in the groups where the extract was added. Similar findings in the literature correlate such results with the type of additive used and the thermal processes applied [45]. The decrease in cooking yield due to the addition of Berberis extract underscores the importance of understanding the impact of the extract's composition and thermal properties during the cooking process. Further detailed analysis is warranted to ascertain whether the extract has an augmenting effect on fat and moisture separation. Moreover, existing literature findings support and enrich the general knowledge regarding the impact of extract additions on cooking yield.

The sensory analysis results for the beef patties are given in Fig. 2.

Figure 2. The sensory analysis results for the beef patties. The columns in the table represent the mean of three replicates, and the vertical bars indicate the standard error of the mean. Distinct letters denote

statistically significant variances based on Duncan's multiple range test ($p < 0.05$).

The addition of the extract did not significantly alter the sensory characteristics of the patties. However, according to the data in the table, panelists generally acknowledged an improvement in sensory features with an increase in the extract proportion. Despite the absence of statistically significant changes, the data from the table indicate a general trend of improvement in sensory attributes with the increase in the extract proportion. While statistical significance may not have been achieved, qualitative assessments by the panelists suggest a trend of improvement in sensory features with the increasing extract proportion. This implies that the extract may have the potential to positively influence the overall sensory profile of the patties, albeit in a subtle but potentially beneficial manner, impacting aspects such as flavor, aroma, or texture. Although statistical significance may not have been established, qualitative observations by the panelists hint at a potential relationship between the extract proportion and sensory attributes.

Texture analysis results for the beef patties are given in Table 3.

Table 3
Texture analysis results (Mean $\pm$ SD)

	Raito (%)				
	0	0,1	0,2	0,4	Sig
Hardness(N)	62,49 $\pm$ 6,89a	72,29 $\pm$ 8,87ab	88,78 $\pm$ 7,016c	82,40 $\pm$ 5,013bc	**
Adhesiveness(mJ)	0,40 $\pm$ 0,29a	0,30 $\pm$ 0,13a	0,13 $\pm$ 0,14a	0,13 $\pm$ 0,15a	ns
Resilince	0,24 $\pm$ 0,015a	0,28 $\pm$ 0,01a	0,26 $\pm$ 0,022b	0,25 $\pm$ 0,01ab	ns
Cohesiveness	0,52 $\pm$ 0,01a	0,55 $\pm$ 0,05a	0,60 $\pm$ 0,03b	0,56 $\pm$ 0,03ab	ns
Springeness (mm)	9,24 $\pm$ 0,48a	9,10 $\pm$ 0,59a	9,06 $\pm$ 0,44a	9,44 $\pm$ 0,68a	ns
Gumminess (N)	32,56 $\pm$ 3,07a	40,54 $\pm$ 9,01ab	53,65 $\pm$ 5,64c	46,03 $\pm$ 3,16bc	**
Chewiness (mJ)	299,82 $\pm$ 14,19a	358,90 $\pm$ 53,01a	485,85 $\pm$ 57,78b	433,50 $\pm$ 30,30b	**
Sig (Significance), SD (Standard Deviation), ** $p < 0.01$, * $p < 0.05$ (Significance Levels), ns (Non-significant for $p > 0.05$), and different letters in the same column (a-c) indicating significant differences ($p < 0.05$) are utilized.					

The selection of beef patties by a majority of consumers is often attributed to lower costs, ease of processing, distinct taste, and superior sensory attributes (including stickiness, chewiness, and

hardness) [9]. Texture stands out as a crucial feature influencing patty quality, with consumers generally favoring a firm texture and glossy color [46]. In this study, hardness (N), gumminess (N), and chewiness (mJ) values were highly significant across all groups ($P < 0.01$). As the proportion of the extract increased, higher values for hardness, gumminess, and chewiness were observed compared to the control group. These findings indicate that the extract could significantly impact the textural characteristics of patties, potentially influencing consumer preferences. The observed increase in hardness, gumminess, and chewiness suggests that the extract could enhance the overall sensory experience of patties, making them more appealing to consumers. Further analysis and exploration of these textural changes could provide valuable insights into potential improvements in patty quality due to the extract. Understanding the effects of the extract on the textural properties of patties is a crucial step toward enhancing product quality and meeting consumer expectations.

Conclusion

Differences observed in patty quality may stem from variations in minced meat stability, yield, cooking loss rates, storage duration, and sensory attributes. However, the industrialization and marketability of patties are constrained by the absence of a standardized processing procedure. Patties, rich in macronutrients such as carbohydrates and proteins, have emerged as an alternative to meet consumer demands for both natural and ready-to-eat foods. This study stands out as the first to investigate patties prepared with the direct addition of different levels of *Berberis vulgaris* L. extract, focusing on safety and quality. Results indicate that the direct addition of extract at 0.1%, 0.2%, and 0.4% levels may positively impact the final product's quality. While the extract's addition did not significantly affect moisture, ash content, or color parameters, notable changes were identified in pH and TBARS values. Additionally, these alterations in parameters led to a reduction in cooking yield. Consequently, recommending lower extract proportions as additive material for patties in such instances may be prudent.

In conclusion, further advanced studies are imperative to comprehensively understand the impact of extract proportions during implementation, optimize extract varieties, and experiment with diverse cooking methods. Insights from these endeavors will contribute to a more nuanced understanding of the potential benefits of *Berberis vulgaris* L. extract in patty production, aiding in the formulation of effective application strategies.

Declarations

Author Contribution

All authors contributed significantly to the research and preparation of this manuscript. KCT conceptualized and designed the study. KCT and GU conducted the experiments, collected. KCT analyzed the data, provided critical insights into data interpretation and drafted the manuscript for important intellectual content. Both authors approved the final version of the manuscript for submission and publication.

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References

1. Wells, J. C., Marphatia, A. A., Amable, G., Siervo, M., Friis, H., Miranda, J. J., Raubenheimer, D. (2021). The future of human malnutrition: rebalancing agency for better nutritional health. *Globalization and health*, 17(1), 1–25.
2. Lee, H. J., Yong, H. I., Kim, M., Choi, Y. S., Jo, C. (2020). Status of meat alternatives and their potential role in the future meat market—A review. *Asian-Australasian journal of animal sciences*, 33(10), 1533.
3. Ogundipe, O. O., Fasogbon, B. M., Ayeke, A. O., Nwosu, P. N., Adebayo-Oyetoro, A. O., Faloye, O. R. (2023). Quality evaluation of beef patties formulated with wheat and sweet potato flour blends. *Food Science and Applied Biotechnology*, 6(2), 187–199.
4. Majeed, T., Maqbool, N., Sajad, A., Aijaz, T., Khan, Z. S. (2024). Meat as a Functional Food for Health. In *Functional Foods* (pp. 177–205). CRC Press.
5. Ergezer, H., Serdaroğlu, M. (2018). Antioxidant potential of artichoke (*Cynara scolymus* L.) byproducts extracts in raw beef patties during refrigerated storage. *Journal of Food Measurement and Characterization*, 12, 982–991.
6. Mor-Mur, M., Yuste, J. (2010). "Emerging bacterial pathogens in meat and poultry: an overview", *Food and Bioprocess Technology*. 3 1.
7. Wu, L., Zhang, C., Long, Y., Chen, Q., Zhang, W., Liu, G. (2022). Food additives: From functions to analytical methods. *Critical reviews in food science and nutrition*, 62(30), 8497–8517.
8. Domínguez, R., Pateiro, M., Munekata, P. E., McClements, D. J., Lorenzo, J. M. (2021). Encapsulation of bioactive phytochemicals in plant-based matrices and application as additives in meat and meat products. *Molecules*, 26(13), 3984.
9. Manessis, G., Kalogianni, A. I., Lazou, T., Moschovas, M., Bossis, I., Gelasakis, A. I. (2020). Plant-derived natural antioxidants in meat and meat products. *Antioxidants*, 9(12), 1215.
10. Meng, X., Wu, D., Zhang, Z., Wang, H., Wu, P., Xu, Z., Gao, Z., Mintah, B.K., Dabbour, M. (2022). An overview of factors affecting the quality of beef meatballs: Processing and preservation. *Food Science & Nutrition*, 10(6), 1961–1974.
11. Kirkyol, M., Akköse, A. (2023). Effects of animal fat replacement with almond flour on quality parameters of beef patties. *Food Science & Nutrition*.
12. Karre L., Lopez K. Getty K.J.K. (2013): Natural antioxidants in meat and poultry products. *Meat Science*, 94: 220–227.

13. Falowo, A.B., Fayemi, P.O., Muchenje, V. (2014): Natural antioxidants against lipid-protein oxidative deterioration in meat and meat products: a review. *Food Research International*, 64: 171–181.
14. Gutiérrez-del-Río, I., López-Ibáñez, S., Magadán-Corpas, P., Fernández-Calleja, L., Pérez-Valero, Á., Tuñón-Granda, M., Miguélez, E.M., Villar, C.J., Lombó, F. (2021). Terpenoids and polyphenols as natural antioxidant agents in food preservation. *Antioxidants*, 10(8), 1264.
15. Ribeiro, J. S., Santos, M. J. M. C., Silva, L. K. R., Pereira, L. C. L., Santos, I. A., da Silva Lannes, S. C., da Silva, M. V. (2019)."Natural antioxidants used in meat products: A brief review", *Meat science*. 148.
16. Yang, L., Zhang, Z., Hu, X., You, L., Khan, R. A. A., Yu, Y. (2022). Phenolic contents, organic acids, and the antioxidant and bio activity of wild medicinal Berberis plants-as sustainable sources of functional food. *Molecules*, 27(8), 2497.
17. Gruenwald J., Brendler T., Jaenicke C. (2007). PDR for herbal medicines fourth edition. Thomson.
18. Sobhani, Z., Akaberi, M., Amiri, M. S., Ramezani, M., Emami, S. A., Sahebkar, A. (2021). Medicinal species of the genus Berberis: a review of their traditional and ethnomedicinal uses, phytochemistry and pharmacology. *Pharmacological Properties of Plant-Derived Natural Products and Implications for Human Health*, 547–577.
19. Blumenthal, M., Busse, W.R., Goldbert, A., Gruenwald, J., Hall, T., Klein, S., Riggins, (1998). The complete German E monographs-therapeutic guide to herbal medicines. *American Botanical Council, Austin, TX*, 310.
20. Gacche, R.N., Dhole, N.A., 2006. Antioxidant and possible anti-inflammatory potential of selected medicinal plants prescribed in the Indian traditional system of medicine. *Pharm. Biol.* 44, 389–395.
21. Kumaran, A., Karunakaran, R. J. (2007). In vitro antioxidant activities of methanol extracts of five *Phyllanthus* species from India. *LWT-Food Science and Technology*, 40(2), 344–352.
22. Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free radical biology and medicine*, 26(9–10), 1231–1237.
23. McDonald, S., Prenzler, P.D., Antolovich, M., Robards, K. (2001). Phenolic content and antioxidant activity of olive extracts. *Food Chemistry*, 73(1): 73–84.
24. AOAC. (2005). Meat and meat products. Chapter 39. In W. Horwitz (Ed.), *Official methods of analysis* (18th ed., pp. 8). AOAC International
25. Gökalp, H.Y., Kaya, M., Tülek, Y., Zorba, O. (2010). Et ürünlerinde kalite kontrolü ve laboratuvar uygulama klavuzu (4. Baskı). Atatürk Üniversitesi Yayınları, Yayın No: 751. Ziraat Fakültesi Yayın No: 318, Atatürk Üniviversitesi Ofset Tesisi, Erzurum.
26. Lemon, D.W. (1975). An improved TBA test for rancidity new series circular. No:51.Halifax-Laboratory, Halifax, Nova Scotia.
27. Murphy, E. W., Criner, P. E., Gray, B. C. (1975). Comparisons of methods for calculating retentions of nutrients in cooked foods. *Journal of agricultural and food chemistry*, 23(6), 1153–1157.

28. Reihani, S.F.S., Tan, T-C., Huda, N., Easa, A.M. (2014). Frozen storage stability of beef patties incorporated with extracts from ulam raja leaves (*Cosmos caudatus*). Food Chemistry, 155: 17–23.
29. Blackburn, C.de W. (2006). 'Microbiological testing in food safety and quality'. Mead, G. (Ed.) *Microbiological analysis of red meat, poultry and eggs*. management' Woodhead Publishing. Page:15.
30. Nieto, G., Martínez-Zamora, L., Peñalver, R., Marín-Iniesta, F., Taboada-Rodríguez, A., López-Gómez, A., Martínez-Hernández, G. B. (2023). Applications of Plant Bioactive Compounds as Replacers of Synthetic Additives in the Food Industry. Foods, 13(1), 47.
31. Rahaman, M. M., Hossain, R., Herrera-Bravo, J., Islam, M. T., Atolani, O., Adeyemi, O. S., Owolodun, O.A., Kambizi, L., Durna Daştan, S., Calina, D., Sharifi-Rad, J. (2023). Natural antioxidants from some fruits, seeds, foods, natural products, and associated health benefits: An update. Food Science & Nutrition, 11(4), 1657–1670.
32. Asadi, N. S., Heidari, M. M., Khatami, M. (2019). Protective effect of *Berberis vulgaris* on Fenton reaction-induced DNA cleavage. Avicenna journal of phytomedicine, 9(3), 213.
33. Eroğlu, A.Y., Çakır, Ö., Sağdıç, M., Dertli, E. (2020). Bioactive Characteristics of Wild *Berberis vulgaris* and *Berberis crataegina* Fruits. Journal of Chemistry. 1–9.
34. Moghaddam, A. R. N., Bahram, A., Ahmad, B., Leila, S., Ali, T. (2021). The First Successful Report: Control of Browning Problem in in vitro Culture of Iranian Seedless Barberry, a Medicinally Important Species. Erwerbs-Obstbau, 63(3), 319–329.
35. Erdoğan, B., Özdestan-Ocak, Ö. (2022). Inhibitory effects of carob and propolis extracts on the formation of heterocyclic aromatic amines in beef patties cooked with different methods. Journal of Food Processing and Preservation, 46(7), e16623.
36. Sheridan, P. S., Shilton, N. C. (2002). Analysis of yield while cooking beef-burger patties using far infrared radiation. Journal of Food Engineering, 51, 3–11. [https://doi.org/10.1016/S0260-8774\(01\)00029-2](https://doi.org/10.1016/S0260-8774(01)00029-2)
37. Del Pulgar, J. S., Gázquez, A., Ruiz-Carrascal, J. (2012). Physico-chemical, textural and structural characteristics of sous-vide cooked pork cheeks as affected by vacuum, cooking temperature, and cooking time. Meat science, 90(3), 828–835.
38. Kivikari, R. (1996). Analysis of sodium in meat products using an Na-selective electrode. In *Proc. of Meat Day Seminar* (No. 536, pp. 64–66).
39. Puolanne, E. J., Ruusunen, M. H., Vainionpää, J. I. (2001). Combined effects of NaCl and raw meat pH on water-holding in cooked sausage with and without added phosphate. Meat science, 58(1), 1–7.
40. Choi, Y. S., Sung, J. M., Park, J. D., Hwang, K. E., Lee, C. W., Kim, T. K., Jeon, K. H., Kim, C. J., Kim, Y. B. (2016). Quality and sensory characteristics of reduced fat chicken patties with pork back fat replaced by dietary fiber from wheat sprout. Korean Journal for Food Science of Animal Resources, 36(6), 799–806. <https://doi.org/10.5851/kosfa.2016.36.6.799>

41. Taşkıran, M., Olum, E., Candoğan, K. (2020). Changes in chicken meat proteins during microwave and electric oven cooking. *Journal of Food Processing and Preservation*, *44*(2), e14324.
42. Ahn, J., Grün, I. U. (2005). Heterocyclic amines: 2. Inhibitory effects of natural extracts on the formation of polar and nonpolar heterocyclic amines in cooked beef. *Journal of food science*, *70*(4), C263-C268.
43. Mahapatra, G., Biswas, S., Banerjee, R. (2021). Improving the quality and shelf-life of chevon meatballs by incorporating fruit and fruit by-products. *Indian J. Anim. Sci*, *90*, 1655–1662.
44. Pietrasik, Z., Li-Chan, E. C. Y. (2002). Binding and textural properties of beef gels as affected by protein, κ -carrageenan and microbial transglutaminase addition. *Food Research International*, *35*(1), 91–98.
45. Turp, G. Y., Icier, F., Kor, G. (2016). Influence of infrared final cooking on color, texture and cooking characteristics of ohmically pre-cooked meatball. *Meat Science*, *114*, 46–53.
46. Huda, N., Shen, Y. H., Huey, Y. L., Ahmad, R., Mardiah, A. (2010). Evaluation of physico-chemical properties of Malaysian commercial beef meatballs. *American Journal of Food Technology*, *5*(1), 13–21.

Figures

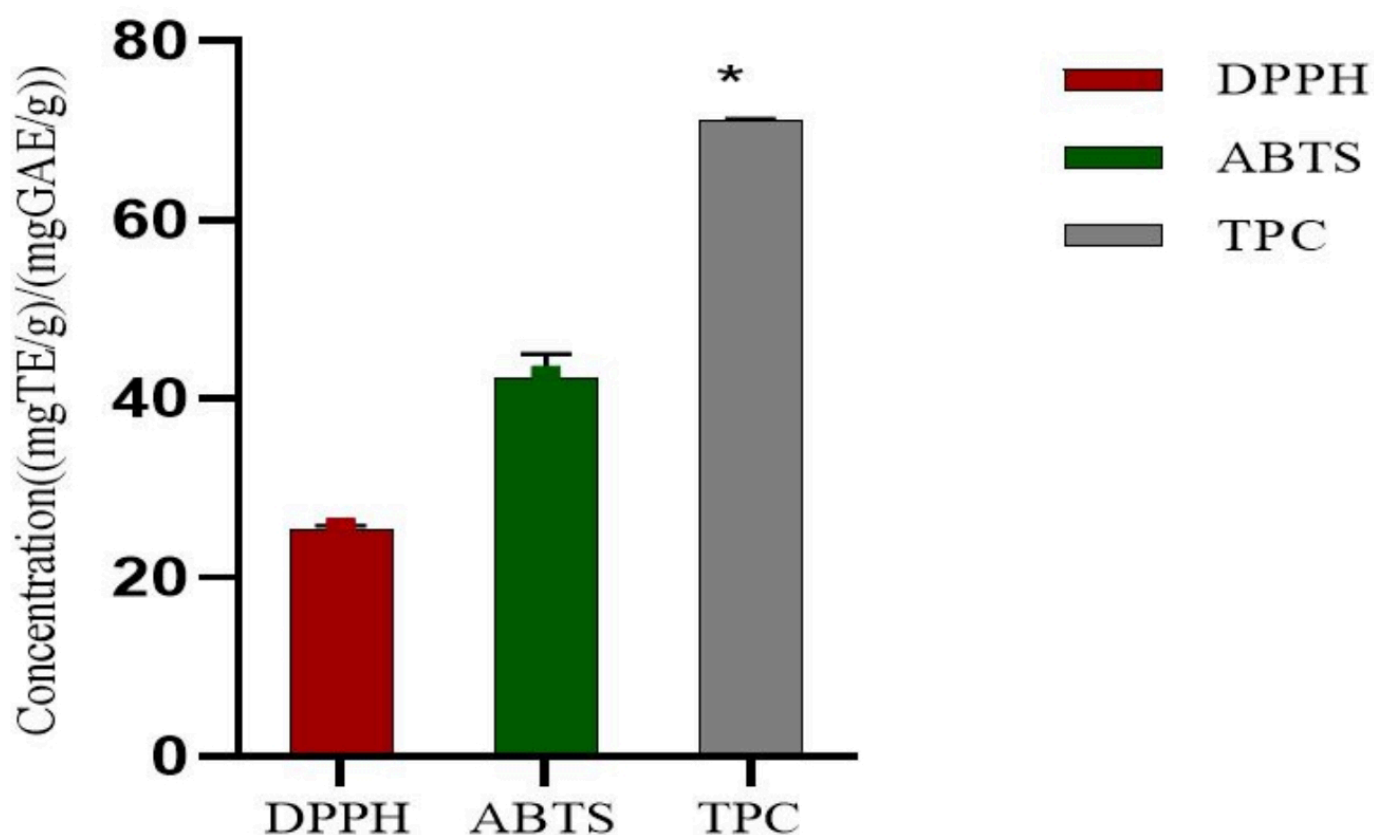


Figure 1

Antioxidant activity and total phenolic content of fruits. The columns in the table represent the mean of three replicates, and the vertical bars indicate the standard error of the mean. Values marked with * within each row are significantly different according to ANOVA ($p < 0.05$).

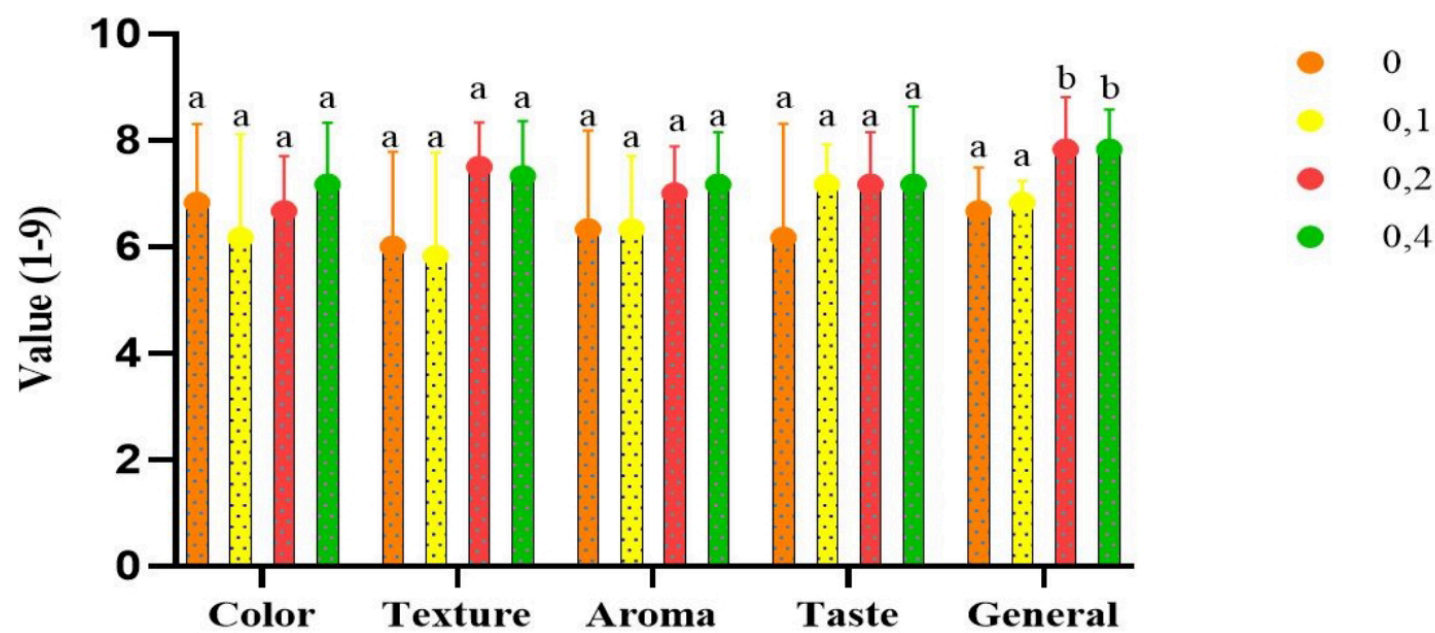


Figure 2

The sensory analysis results for the beef patties. The columns in the table represent the mean of three replicates, and the vertical bars indicate the standard error of the mean. Distinct letters denote statistically significant variances based on Duncan's multiple range test ($p < 0.05$).