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Research Article/Araştırma Makalesi

Potential use of fig peel powder as a fat replacer and functional ingredient in beef patties

İncir kabuğu tozunun, yağ ikame edici ve fonksiyonel bileşen olarak sığır köftelerinde kullanım potansiyeli

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ABSTRACT

The peels of figs can be considered a valuable source of essential nutrients for food enrichment, as they contain high levels of bioactive substances with nutritional potential. In this study, fig peel powder (FPP) was used as a fat replacer and functional ingredient in beef patties. Five different beef patty formulations were prepared with 0, 0.75, 1.5, 2.25, and 3% replacement of beef fat with FPP. Adding FPP reduced the moisture and fat, while increased ash content in patties. A reduction in fat content of about 4-14% was observed. The treatment of FPP improved the cooking loss and hardness of beef patties. In contrast, adding FPP decreased lightness and pH values, but the pH values of all patties were compliant with the Turkish Uncooked Meatball Standard. Regarding the overall acceptability, beef patties formulated with 3% FPP received the lowest score, but the differences between all treatment groups were non-significant (P>0.05). It is concluded that adding 3% FPP could be recommended as a fat replacer and functional ingredient in beef patties with minimal compositional and sensory changes.

Key Words: Beef patty, fig peel, fat replacer, functional ingredient

ÖZ

İncir kabukları, yüksek miktarda besleyici potansiyele sahip biyoaktif bileşikler içerdiklerinden, gıdaların besinsel açıdan zenginleştirilmesinde değerli bir kaynak olarak düşünülebilirler. Bu çalışmada, incir kabuğu tozu (İKT), sığır köftelerinde yağ ikame edici ve fonksiyonel bir bileşen olarak kullanılmıştır. Sığır yağının %0, %0.75, %1.5, %2.25 ve %3'ünün İKT ile ikame edildiği beş farklı köfte formülasyonu hazırlanmıştır. İKT ilavesi, köftelerde nem ve yağ miktarını azaltırken kül içeriğini artırmıştır. Yağ içeriğinde yaklaşık %4-14 oranında bir azalma gözlemlenmiştir. İKT uygulaması, köftelerin pişirme kaybını ve sertliğini iyileştirmiştir. Buna karşın, İKT ilavesi köftelerin açıklığını (renk parlaklığını) ve pH değerlerini düşürmüş, ancak tüm köftelerin pH değerleri Türk Çiğ Köfte Standardı ile uyumlu bulunmuştur. Genel kabul edilebilirlik açısından, %3 İKT içeren köfteler en düşük puanı almış, ancak tüm uygulama grupları arasındaki farklar önemsiz bulunmuştur (P>0.05). Sığır köftelerinde yağ ikame maddesi ve fonksiyonel bileşen olarak %3 oranında İKT ilavesinin, minimal bileşimsel ve duyusal değişikliklerle önerilebileceği sonucuna varılmıştır.

Anahtar Kelimeler: Sığır köftesi, incir kabuğu, yağ ikame edici, fonksiyonel bileşen

Introduction

Meat and meat-derived products are a significant component of the human diet due to their high-quality proteins and valuable nutrients, such as iron, vitamin B12, and folic acid (Arihara, 2006; Bilek & Turhan, 2009). Nevertheless, their consumption has been subject to ongoing debate, mainly due to health concerns associated with excessive intake or particular dietary conditions (Jimenez-Colmenero et al., 2001; Bilek & Turhan, 2009). These concerns largely stem from the presence of fat, saturated fatty acids, and cholesterol, which have been linked to obesity, certain types of cancer, elevated blood cholesterol levels, hypertension, and cardiovascular diseases (Fernandez-Gines et al., 2005; Turhan et al., 2005; Bilek & Turhan, 2009). Additionally, these products generally lack dietary fiber, which is vital for a balanced diet (Öztürk & Turhan, 2020). On the other hand, reducing fat levels in processed meat products may negatively impact both technological features (e.g., decreased yield, higher cooking losses, reduced emulsion stability) and sensory qualities (e.g., producing harder, drier, less juicy, and less palatable products) (Selani et al., 2016; Öztürk & Turhan, 2020; Ran et al., 2020). Therefore, replacing beef fat with suitable alternatives and enriching meat products with dietary fiber and bioactive compounds has become essential.

Many natural sources, such as hazelnut pellicle (Turhan et al., 2005), flaxseed flour (Bilek & Turhan, 2009), potato puree and bread crumbs (Ergezer et al., 2014), adzuki beans (Aslinah et al., 2018), pumpkin seed flour (Öztürk & Turhan, 2020), pennyroyal powder (Guliyeva & Turhan, 2021), peanut skin (Bıyık & Turhan, 2022), and black rice extract (Soyocak et al., 2024), have been investigated to replace beef fat and enrich meat products with dietary fiber and other bioactive components. Fruit and vegetable by-products are also promising, as they remain rich in valuable bioactive compounds that can be recovered and incorporated into food formulations. In this context, fig (*Ficus carica* L.) stands out as an important crop, with Türkiye contributing around 26% of global production (Panza et al., 2022). Figs are abundant in crude fiber, minerals, and vitamins; they are free of fat, sodium, and cholesterol; and they contain amino acids and numerous bioactive compounds, including polyphenols, anthocyanins, and carotenoids (Viuda-Martos et al., 2015; Panza et al., 2022; Alzahrani et al., 2024). During fig processing for products such as puree, juice, or jam, considerable amounts of by-products are generated, which remain rich in these compounds (Panza et al., 2022). Fig peels, accounting for about 27% of the total fruit weight, are particularly valuable, as they contain tocols, organic acids, flavonoids, triterpenoids, and phenolic acids with nutritional potential (Alzahrani et al., 2024). Hence, figs and their by-products can be considered valuable functional food ingredients.

Few studies have been reported on the application of fig by-products (leaves, peel, and seeds) to foods. Most of these studies are on cereal products such as cookies (Khapre et al., 2015), muffins (Özkan & Gül, 2021), biscuits (Bölek, 2021; Berrighi, 2025), and pasta (Panza et al., 2022). There is also a study on fermented goat meat sausage (Aung et al., 2025), sucuk (Kurt, 2012), and toffees (Khapre et al., 2011). To the best of our knowledge, there is no information on the use of fig peel powder (FPP) as a fat replacer and functional ingredient in beef patties. Therefore, this study aimed to evaluate the effect of using FPP instead of beef fat in beef patties on certain physicochemical and sensory properties of the beef patties, to develop a healthier and more functional product.

Materials and Methods

Materials

The peels of fig (*Ficus carica* L.) variety 'Sarılop' were used for this study. Mature fruits were obtained from a farmer in Samsun, Atakum. Fruits were manually peeled, and the peels were dried in a hot-air oven (JSR, JSOF-50 model, Korea) at 60 °C for 2 days. After drying, they were powdered with a blender (Waring-8011ES, Stamford, USA), passed through a 0.5 µm sieve, and stored in a glass container at +4 °C until required. FPP's moisture, protein, fat, and ash amounts were 11.78%, 4.28%, 4.48%, and 3.0%, respectively, and were determined according to the procedures outlined in AOAC (2000). Ground beef (62.63% moisture, 18.87% protein, 16.27% fat, and 0.96% ash), beef fat (18.58% moisture and 78.07% fat), and other ingredients (breadcrumbs, salt, and garlic powder) were purchased from Florya Meat Industry in Samsun, Türkiye. The moisture, protein, fat, and ash amount of ground beef, as well as the moisture and fat content of beef fat, were also determined according to the procedures outlined in AOAC (2000).

Preparation of beef patties

All experiments were performed at the Pilot Meat Processing Unit of the Food Engineering Department, Ondokuz Mayis University, Türkiye. Ground beef was portioned into five groups, and the first group was used as the control by adding 20% beef fat. In the other experimental groups, beef fat was partially substituted with FPP at levels of 0.75%, 1.5%, 2.25%, and 3%. All formulations included 5% breadcrumbs, 1.5% salt, and 1% garlic powder (Table 1). Each 1 kg group was hand-mixed (with gloves) for 10 min, divided into ~30 g portions, and manually shaped into patties. Samples were packed in polyethylene bags and stored at +4 °C until analysis. The experiment was repeated twice on separate days.

Table 1. Formulations of beef patties with different fig peel powder levels

Ingredients (%, w/w)	Fig peel powder level (%)				
	0 (control)	0.75	1.5	2.25	3
Ground beef	72.5	72.5	72.5	72.5	72.5
Beef fat	20	19.25	18.5	17.75	17
Fig peel powder	0	0.75	1.5	2.25	3
Breadcrumbs	5	5	5	5	5
Salt	1.5	1.5	1.5	1.5	1.5
Garlic powder	1	1	1	1	1
Total	100	100	100	100	100

Compositional and physicochemical characterization of beef patties

Proximate composition (moisture, protein, fat, and ash content) was determined according to the procedures outlined in AOAC (2000) and expressed as a percentage.

Cooking loss (CL) and diameter reduction (DR) were determined by grilling the patties on an electric grill (Arçelik Midi Oven, Türkiye) for a total of 7 min, consisting of 5 min on one side followed by 2 min on the opposite side. Weights and diameters were measured before and after cooking for calculations (Turhan et al., 2005).

Water holding capacity (WHC) was assessed using the filter paper press technique (Öztan & Vural, 1993). A 1 g sample was placed between filter papers, pressed under 1 kg for 1 h, and the liquid area was measured with a digital planimeter (Koizumi Placom KP-90 N, Japan). WHC was calculated as:

$$WHC = \frac{Pressed\ sample\ area\ (cm^2)}{Total\ liquid\ area\ (cm^2)} \quad (1)$$

pH was measured after homogenizing 10 g of the sample in 100 mL of distilled water, using a calibrated digital pH meter (Cyberscan PC 510, Singapore).

Surface color was determined with a Minolta CR-300 colorimeter, recording CIELAB values *L** (lightness), *a** (redness), and *b** (yellowness).

Textural properties were analyzed with a Texture Analyzer (TA-XT Plus, Stable Micro Systems, UK) using a 50 mm cylindrical probe (model P/50R) and a 2 kg load cell. Samples (~50 mm diameter, 10 mm thickness) were compressed twice at 60% strain. Hardness, springiness, cohesiveness, and chewiness were calculated from force-time curves (Öztürk & Turhan, 2020).

Sensory evaluation of beef patties

Cooked patties (prepared as in CL/DR tests) were evaluated by a panel of 10 experienced assessors (faculty and skilled evaluators, Ondokuz Mayis University, Samsun). Tests were carried out in a sensory laboratory under fluorescent light. Raw patties were scored for appearance, while cooked samples were assessed for flavor, juiciness, and tenderness. A 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) was used. Overall acceptability was calculated as the mean of the four attributes, each weighted equally (Turhan et al., 2014).

Statistical analysis

All analyses were carried out in duplicate, and results were expressed as mean ± standard deviation (SD). Data were subjected to one-way ANOVA, and differences among means were tested using Duncan's multiple range test at $P<0.05$. SPSS 21.0 (IBM, Chicago, IL, USA) was used for statistical processing.

Results and Discussion

Compositional and physicochemical properties of beef patties formulated with FPP

The compositional and physicochemical properties of beef patties with different FPP levels were determined, and the results are presented in Table 2. As seen, except for protein, other compositional parameters of beef patties (moisture, fat, and ash) were affected by replacing beef fat with FPP ($P<0.05$), and the ash content increased as the amount of FPP increased, while the moisture and fat contents decreased. For instance, the fat content decreased by 4.32%, 6.97%, 8.29%, and 13.91% with the addition of 0.75%, 1.5%, 2.25%, and 3% FPP, respectively. However, all formulations remained within the compositional limits specified by the Turkish Uncooked Meatball Standard (TSE, 2002). The observed changes are likely due to the inherent composition of FPP, which contains more ash and less moisture and fat than beef fat. Similarly, numerous studies demonstrated that the incorporation of various food ingredients into comminuted meat products influenced their proximate composition. For example, Turhan et al. (2005) reported that the inclusion of hazelnut pellicle in beef burgers altered their proximate composition, with higher levels of hazelnut pellicle leading to reductions in moisture and protein contents. In line with these findings, Bilek and Turhan (2009) observed that the addition of flaxseed flour to beef patties affected their compositional attributes; Aslinah et al. (2018) reported similar effects when adzuki bean (*Vigna angularis*) flour was incorporated into reduced-fat beef meatballs; and Öztürk and Turhan (2020) indicated that supplementing beef meatballs with pumpkin (*Cucurbita pepo* L.) seed kernel flour likewise resulted in notable alterations in proximate composition.

The CL values of beef patties were affected by replacing beef fat with FPP ($P<0.05$) (Table 2), and the highest value was determined in the control beef patties, probably due to protein denaturation and higher fat loss during cooking (Sayas-Barbera et al., 2020). The CL values of the samples decreased with more FPP addition, and increasing the FPP addition from 0 to 3% reduced the CL from 23.01 to 18.27%. This lower value could be related to the oil absorption or oil-holding capacity of the FPP, which likely enhances lipid retention within the product matrix during cooking. Viuda-Martos et al. (2015) reported that the oil-holding capacity of fig powder co-products obtained from peel and pulp varied from 0.75 to 0.90 g oil/g fiber. In agreement with this, Berrighi (2025) noted that fig flour exhibits notable oil absorption capacity, likely attributable to its low hydrophobic protein content, which confers an enhanced ability to bind lipids. Various researchers also reported that the addition of plant-based ingredients to comminuted meat products reduced cooking losses. For example, Turhan et al. (2005) reported that cooking loss, which was 46.19% in control beef burgers without hazelnut pellicle, decreased with the addition of hazelnut pellicle, and decreased to 25.20% in those containing 5% hazelnut pellicle. Similarly, Yilmaz (2005) also reported that the incorporation of wheat bran into meatball formulations led to reduced weight loss during cooking, with the lowest value (9.15%) observed in samples containing 20% wheat bran. In the study conducted by Bilek and Turhan (2009), it was also reported that adding flaxseed flour to beef patties improved cooking loss, and the cooking loss, which was 30.16% in 10% fat control meatballs, decreased to 22.02% in those containing 15% flaxseed flour.

The DR and WHC values of beef patties ranged from 10.73 to 11.67% and from 0.76 to 0.83, respectively, but neither DR nor WHC values were affected by replacing beef fat with FPP (P>0.05) (Table 2). Also, similar DR and WHC values were reported by Serdaroğlu et al. (2005) in low-fat meatballs containing legume flours, and similar DR values by Serdaroğlu et al. (2018) in beef patties formulated with pumpkin pulp and seeds. In contrast, the pH values of beef patties were affected by the addition of FPP, but only the pH value of the group containing 3% FPP decreased compared to the control group (P<0.05) (Table 2). This decrease in pH could be attributed to the low pH value of FPP, which was 4.24. However, all samples complied with the pH range specified by the national meatball standard (TSE, 2002). Similarly, various researchers (Yılmaz, 2005; Serdaroğlu et al., 2018; Saraiva et al., 2019) reported that the addition of fat replacers and functional ingredients to comminuted meat products affected the pH value of the product.

Table 2. Compositional and physicochemical properties of beef patties with different fig peel powder levels

Parameters	Fig peel powder level (%)				
	0 (control)	0.75	1.5	2.25	3
Moisture (%)	51.08±0.92a	49.77±0.29ab	49.28±0.69b	49.08±0.54b	48.75±0.17b
Protein (%)	16.06±0.01a	16.11±0.01a	16.21±0.08a	16.23±0.07a	16.26±0.08a
Fat (%)	25.95±0.75a	24.83±0.98ab	24.14±0.48b	23.80±0.04bc	22.34±0.62c
Ash (%)	2.28±0.04b	2.35±0.06ab	2.39±0.04ab	2.42±0.06ab	2.45±0.07a
CL (%)	23.01±0.52a	22.26±0.54ab	21.23±0.76b	19.07±0.78c	18.27±0.26c
DR (%)	10.91±1.26a	10.73±0.47a	11.24±1.16a	11.25±1.16a	11.67±1.10a
WHC	0.76±0.02a	0.83±0.03a	0.77±0.02a	0.79±0.02a	0.81±0.02a
pH	5.75±0.05a	5.75±0.03a	5.73±0.02a	5.74±0.01a	5.63±0.02b

Values are the mean ± SD of two replicates. Different lowercase letters (a-c) denote significant differences among treatment groups in terms of moisture, fat, ash, CL, and pH (P<0.05). CL: cooking loss; DM: diameter reduction; WHC: water holding capacity.

Color and textural properties of beef patties formulated with FPP

The color and textural properties of beef patties with different FPP amounts are given in Table 3. As seen, the *L**, *a**, and *b** values of beef patties ranged from 43.66 to 46.59, from 9.83 to 11.61, and from 10.73 to 11.67, respectively, but only the *L** values showed a significant change when beef fat was replaced with FPP (P<0.05). The addition of FPP to beef patties resulted in a decrease in *L** values compared to the control group (P<0.05), but this decrease was not significant between the control and the 1.5% FPP added group (P>0.05). The reduction in lightness values of the beef patties could be attributed to the natural pigments found in the fig peels. Similarly, various researchers stated that incorporating fig seed powder into the muffins (Özkan & Gül, 2021) and biscuits (Bölek, 2021), as well as adding fig fruit flour to the biscuits (Berrighi, 2025), reduced *L** values depending on the level of addition, and caused the products to be darker. As seen, using FPP in beef patties production only affected the *L** value, and this effect was limited. These results show that the FPP ratios used in the current study do not generally pose much of a problem in terms of color properties.

All textural properties, including hardness, springiness, cohesiveness, and chewiness, were affected by replacing beef fat with FPP (P<0.05) (Table 3). The highest hardness was found in the control beef patties with 173.81 N, and the FPP addition decreased the hardness values. Also, the hardness of beef patties reduced further with the addition of FPP, and the lowest value was determined in beef patties containing 3% FPP as 146.70 N (P<0.05). It is estimated that this is due to the proteolytic enzyme ficin found in fig fruit, which could break down muscle proteins into smaller peptides and amino acids (Azmi et al., 2023). Similarly, Kurt (2012) reported that the hardness values of sucuks added with fresh black figs were markedly lower than those of control sucuks, and this decrease was due to softening caused by proteolytic activity. The springiness values of beef patties ranged from 0.61 to 0.78 mm, and the control group patties exhibited lower springiness values than all patties containing FPP (P<0.05). But, the differences between the springiness values of patties containing FPP at different levels were not significant (P>0.05). With the FPP level increasing from 0.75 to 3%, cohesiveness and chewiness generally increased (P<0.05), but this increase was more pronounced in chewiness values. Such increases for cohesiveness and chewiness were also noted by Bağdatlı (2018) in meatballs with quinoa flour. The current study and many other studies (Turhan et al., 2014; Aslinah et al., 2018; Bağdatlı, 2018) reveal that the textural properties of meat products could differ depending on composition, source, amount of ingredients in the formulation, and the amount of fat substituted.

Table 3. Color and textural properties of beef patties with different fig peel powder levels

Parameters	Fig peel powder level (%)				
	0 (control)	0.75	1.5	2.25	3
Color properties					
*L** (Lightness)	46.59±0.19a	43.82±0.28b	44.85±0.48ab	43.66±1.67b	43.82±0.40b
*a** (Redness)	11.09±1.30a	11.61±1.53a	11.17±1.52a	10.55±0.19a	9.83±0.15a
*b** (Yellowness)	10.91±1.26a	10.73±0.47a	11.24±1.16a	11.25±1.16a	11.67±1.10a
Textural properties					
Hardness (N)	173.81±0.34a	169.44±1.96b	164.81±1.24c	158.26±2.10d	146.70±1.11e
Springiness (mm)	0.61±0.04b	0.76±0.07a	0.76±0.01a	0.78±0.01a	0.76±0.02a
Cohesiveness	0.27±0.01c	0.26±0.01c	0.28±0.01bc	0.30±0.01ab	0.33±0.01a
Chewiness (N. mm)	27.50±1.47b	29.87±2.22b	37.15±0.11a	37.13±1.34a	36.51±1.25a

Values are the mean ± SD of two replicates. Different lowercase letters (a-e) denote significant differences among treatment groups in terms of lightness, hardness, springiness, cohesiveness, and chewiness (P<0.05).

Sensory attributes of beef patties formulated with FPP

Sensory assessments of beef patties with various levels of FPP are displayed in Figure 1. As seen, parameters including appearance, flavor, juiciness, tenderness, and overall acceptability ranged from 7.80 to 7.05, 7.30 to 6.50, 6.90 to 6.30, 7.00 to 6.45, and 7.08 to 6.71, respectively. Despite these differences, no sensory property was affected by replacing beef fat with FPP (P>0.05). Therefore, panelists did not detect any off-flavors or textural defects, and even the 3% FPP samples maintained acceptable sensory characteristics. Regarding the overall acceptability, differences were not significant (P>0.05); all treatments were very similar, but beef patties formulated with 3% FPP received the lowest score. The low levels of FPP added to the beef patties likely contributed to the results observed. Some researchers also noted that using such low levels of non-meat ingredients did not adversely impact the sensory scores of the food products. For example, Sayas-Barbera et al. (2020) added four different concentrations (0, 1.5, 3, and 6%) of date bit powder to beef burgers and subjected them to sensory evaluation by both trained and consumer panels. The trained panel found no differences in the visual color and off-odor of the uncooked burgers. Similarly, the consumer panel reported no significant differences in aroma, flavor, particle detection, cohesiveness, or overall acceptability scores of the burgers. Also, Khapre et al. (2015) noted that when the amount of fig powder increased from 0 to 15%, the taste, color, appearance, texture, flavor, and overall acceptability scores of the Indian cookie did not differ (P>0.05), but the cookie with 12% fig powder had the maximum overall acceptability score. Accordingly, it is evaluated that 3% FPP can be used as a fat replacer and functional ingredient in beef patties.

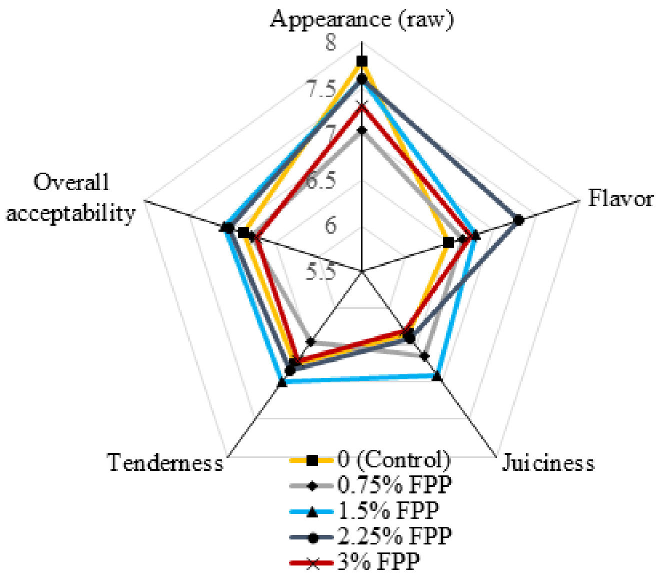

Figure 1. Sensory scores of beef patties with different fig peel powder levels

Conclusions

In the current study, FPP was used as a fat replacer and functional component to make healthier beef patties, and the results showed that it decreased the fat content and improved the cooking loss and hardness. The inclusion of FPP negatively affected the lightness, but the beef patties containing 1.5% of FPP were not significantly different from control patties. The FPP addition affected the compositional parameters (except protein) and pH value of the beef patties, but the proximate composition and pH values with FPP complied with the values specified by the national meatball standard. The sensory evaluation results indicated that overall acceptability scores of beef patties with 3% FPP received the lowest score, but the differences were not significant. Thus, FPP could be used as a fat replacer or functional component in beef patties with minimal compositional and sensory changes, and this situation could represent a new direction for the development and utilization of fig by-products in the food industry.

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Conflict of interest

The authors declare that they have no conflict of interest

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Author contributions

Sadettin Turhan contributed as the thesis supervisor in conducting analyses, statistical analyses of data, writing the article, and writing-review-proofreading-publishing procedures. The thesis student, Hanife Yeşilyurt, carried out the preparation of samples, analyses, reporting, and writing and correction of literature sources. The authors have read and approved the final version of the article.

References

Alzahrani, M. Y., Alshaikhi, A. I., Hazzazi, J. S., Kurdi, J. R., & Ramadan, M. F. (2024). Recent insight on nutritional value, active phytochemicals, and health-enhancing characteristics of fig (*Ficus craica*). *Food Safe Health*, 2, 179-195. DOI: https://doi.org/10.1002/fsh3.12034

AOAC (2000). Official methods of analysis (15th ed.). Washington, DC: Association of Official Analytical Chemists. AOAC International.

Arihara, K. (2006). Strategies for designing novel functional meat products. *Meat Science*, 74, 219-229. DOI: https://doi.org/10.1016/j.meatsci.2006.04.028

Aslinah, L. N. F., Yusoff, M. M., & Ismail-Fitry, M. R. (2018). Simultaneous use of adzuki beans (*Vigna angularis*) flour as meat extender and fat replacer in reduced-fat beef meatballs (bebola daging). *Journal of Food Science and Technology*, 55, 3241-3248. DOI: https://doi.org/10.1007/s13197-018-3256-1

Aung, S. H., Nimantha, R. R., Choi, Y-S, Jang, A., Lee, J. H., & Nam, K-C. (2025). Effects of fig and pineapple powder on metabolite compounds and health-promoting properties in fermented goat meat sausage. *Animal Bioscience*, 38, 752-764. DOI: https://doi.org/10.5713/ab.24.0526

Azmi, S. I. M., Kumar, P., Sharma, N., Sazili, A. Q., Lee, S-J., & Ismail-Fitry, M. R. (2023). Application of plant proteases in meat tenderization: Recent trends and future prospects. *Foods*, 12, 1336. DOI: https://doi.org/10.3390/foods12061336

Bağdatlı, A. (2018). The influence of quinoa (*Chenopodium quinoa* willd.) flour on the physicochemical, textural and sensorial properties of beef meatball. *Italian Journal of Food Science*, 30, 280-288. DOI: https://doi.org/10.14674/IJFS-945

Berrighi, N. (2025). Effects of dried fig flour incorporation as a natural additive on nutritional composition and sensory assessment of biscuit. *Czech Journal of Food Sciences*, 43, 37-47. DOI: https://doi.org/10.17221/187/2024-CJFS

Bıyık, Ş., & Turhan, S. (2022). Evaluation of quality and storage stability of beef patties containing different levels of peanut (*Arachis hypogaea* L.) skin. *The Journal of Food*, 47, 420-433. DOI: https://doi.org/10.15237/gida.GD21130

Bilek, A. E., & Turhan, S. (2009). Enhancement of the nutritional status of beef patties by adding flaxseed flour. *Meat Science*, 82, 472-477. DOI: https://doi.org/10.1016/j.meatsci.2009.03.002

Bölek, S. (2021). Effects of waste fig seed powder on quality as an innovative ingredient in biscuit formulation. *Journal of Food Science*, 86, 55-60. DOI: https://doi.org/10.1111/1750-3841.15548

Ergezer, H., Akcan, T., & Serdaroğlu, M. (2014). The effects of potato puree and bread crumbs on some quality characteristics of low fat meatballs. *Korean Journal for Food Science of Animal Resources*, 34, 561-569. DOI: http://dx.doi.org/10.5851/kosfa.2014.34.5.561

Fernandez-Gines, J. M., Fernandez-Lopez, J., Sayas-Barbera, E., & Perez-Alvarez, J. A. (2005). Meat products as functional foods: A review. *Journal of Food Science*, 70: 37-43. DOI: https://doi.org/10.1111/j.1365-2621.2005.tb07110.x

Guliyeva, F., & Turhan, S. (2021). Assessment of physicochemical and sensory quality of beef patties formulated with pennyroyal (*Mentha pulegium* L.) powder. *The Journal of Food*, 46, 739-750. DOI: https://doi.org/10.15237/gida.GD21011

Jimenez-Colmenero, F., Carballo, J., & Cofrades, S. (2001). Healthier meat and meat products: Their role as functional foods. *Meat Science*, 59, 5-13. DOI: https://doi.org/10.1016/s0309-1740(01)00053-5

Khapre, A. P., Satwadhar, P. N., & Deshpande, H. W. (2011). Development of technology for preparation of fig (*Ficus carica* L.) fruit powder and its utilization in toffee. *Journal of Dairying Foods & Home Sciences*, 30, 267-270.

Khapre, A. P., Satwadhar, P. N., & Syed, H. M. (2015). Studies on processing technology and cost estimation of fig (*Ficus carica* L.) fruit powder enriched Burfi (Indian cookie). *Journal of Applied and Natural Science*, 7, 621-624. DOI: https://doi.org/10.31018/jans.v7i2.655

Kurt, A. (2012). Utilization of dried fig and fresh black fig in fermented sucuk production. Afyon Kocatepe University, Graduate School of Natural and Applied Sciences, Department of Food Engineering, M.Sc. Thesis, Afyonkarahisar.

Özkan, H., & Gül, H. (2021). Effects of fig seed flour on physical, chemical, textural and sensory quality of muffin. *Journal of Adnan Menderes University Agricultural Faculty*, 18, 33-39. DOI: https://doi.org/10.25308/aduziraat.786257

Öztan, A., & Vural, H. (1993). A study on the changes of water holding capacity and the free water proportion of beef. *The Journal of Food*, 18, 29-33.

Öztürk, T., & Turhan, S. (2020). Physicochemical properties of pumpkin (*Cucurbita pepo* L.) seed kernel flour and its utilization in beef meatballs as a fat replacer and functional ingredient. *Journal of Food Processing and Preservation*, 44, e14695. DOI: https://doi.org/10.1111/jfpp.14695

Panza, O., Conte, A., & Del Nobile, M. A. (2022). Recycling of fig peels to enhance the quality of handmade pasta. *LWT - Food Science and Technology*, 168, 113872. DOI: https://doi.org/10.1016/j.lwt.2022.113872

Ran, M., Chen, C., Li, C., He, L., & Zeng, X. (2020). Effects of replacing fat with Perilla seed on the characteristics of meatballs. *Meat Science*, 161, 107995. DOI: https://doi.org/10.1016/j.meatsci.2019.107995

Saraiva, B. R., Agustinho, B. C., Vital, A. C. P., Staub, L., & Pintro, P. T. M. (2019). Effect of brewing waste (malt bagasse) addition on the physicochemical properties of hamburgers. *Journal of Food Processing and Preservation*, 43, e14135. DOI: https://doi.org/10.1111/jfpp.14135

Sayas-Barbera, E., Martín-Sánchez, A. M., Cherif, S., Ben-Abda, J., & Pérez-Álvarez, J. A. (2020). Effect of date (*Phoenix dactylifera* L.) pits on the shelf life of beef burgers. *Foods*, 9, 102. DOI: https://doi.org/10.3390/foods9010102

Selani, M. M., Shirado, G. A. N., Margiotta, G. B., Rasera, M. L., Marabesi, A. C., Piedade, S. M. S., Contreras-Castillo, C. J., & Canniatti-Brazaca, S. G. (2016). Pineapple by-product and canola oil as partial fat replacers in low-fat beef burger: Effects on oxidative stability, cholesterol content and fatty acid profile. *Meat Science*, 115, 9-15. DOI: https://doi.org/10.1016/j.meatsci.2016.01.002

Serdaroğlu, M., Yıldız-Turp, G., & Abrodimov, K. (2005). Quality of low-fat meatballs containing legume flours as extenders. *Meat Science*, 70, 99-105. DOI: https://doi.org/10.1016/j.meatsci.2004.12.015

Serdaroğlu, M., Kavuşan, H. S., İpek, G., & Öztürk, B. (2018). Evaluation of the quality of beef patties formulated with dried pumpkin pulp and seed. *Korean Journal for Food Science of Animal Resources*, 38, 1-13. DOI: https://doi.org/10.5851/kosfa.2018.38.1.001

Soyocak, H., Proestos, C., Brennan, C., Wahab, R., Oz, F., & Turhan, S. (2024). The preservative effect of the black rice's cold, hot, and ultrasonic ethanol extracts on the storage quality of beef patties. *International Journal of Food Science & Technology*, 59, 9445-9458. DOI: https://doi.org/10.1111/ijfs.17593

TSE (2002). Turkish Uncooked Meatball Standard, TSE 10581. Turkish Standards Institution, Ankara.

Turhan, S., Sagir, I., & Ustun, N. S. (2005). Utilization of hazelnut pellicle in low-fat beef burgers. *Meat Science*, 71, 312-316. DOI: https://doi.org/10.1016/j.meatsci.2005.03.027

Turhan, S., Yazici, F., Saricaoglu, F. T., Mortas, M., & Genccelep, H. (2014). Evaluation of the nutritional and storage quality of meatballs formulated with bee pollen. *Korean Journal for Food Science of Animal Resources*, 34, 423-433. DOI: http://dx.doi.org/10.5851/kosfa.2014.34.4.423

Viuda-Martos, M., Barber, X., Pérez-Álvarez, J. A., & Fernández-López, J. (2015). Assessment of chemical, physicochemical, techno-functional and antioxidant properties of fig (*Ficus carica* L.) powder co-products. *Industrial Crops and Products*, 69, 472-479. DOI: https://doi.org/10.1016/j.indcrop.2015.03.005

Yılmaz, I. (2005). Physicochemical and sensory characteristics of low fat meatballs with added wheat bran. *Journal of Food Engineering*, 69, 369-373. DOI: https://doi.org/10.1016/j.jfoodeng.2004.08.028