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EVALUATION OF QUALITY AND STORAGE STABILITY OF BEEF PATTIES CONTAINING DIFFERENT LEVELS OF PEANUT (*Arachis hypogaea* L.) SKIN

Şule Bıyık, Sadettin Turhan*
Department of Food Engineering, Engineering Faculty, Ondokuz Mayis University, Samsun, Turkey

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ABSTRACT
The present study was conducted to evaluate the quality and storage stability of beef patties containing different levels of peanut skin (PS) during cold storage. The PS showed a high phenolic content and antioxidant capacity. The addition of PS enhanced the water holding capacity of patties while negatively affected the protein content, hardness, and chewiness. The treatment of PS decreased appearance, juiciness, and overall acceptability scores, but overall acceptability scores of beef patties containing up to 4.5% PS were similar to the negative control without PS. The incorporation of PS to beef patties at high levels (3.0, 4.5, and 6.0%) stabilized the pH, lipid oxidation, color differences, and microbial growth during the storage period. Thus, the inclusion of 4.5% PS could be recommended to prolong the shelf life of beef patties with minimal compositional and sensory changes.
Keywords: Beef patty, peanut skin, quality evaluation, storage stability

FARKLI DÜZEYLERDE YER FISTIĞI (*Arachis hypogaea* L.) ZARI İÇEREN SIĞIR KÖFTELERİNİN KALİTE VE DEPOLAMA STABİLİTESİNİN DEĞERLENDİRİLMESİ

ÖZ
Bu çalışma, farklı düzeylerde yer fıstığı zarı (YFZ) içeren sığır köftelerinin soğuk depolama sırasında kalite ve depolama stabilitesini değerlendirmek için gerçekleştirilmiştir. YFZ, yüksek fenolik içerik ve antioksidan kapasite sergilemiştir. YFZ ilavesi köftelerin su tutma kapasitesini artırırken, protein içeriğini, sertliğini ve çiğnenebilirliğini olumsuz yönde etkilemiştir. YFZ uygulaması, görünüm, sululuk ve genel kabul edilebilirlik puanlarını azaltmış ancak %4.5'e kadar YFZ içeren köftelerin genel kabul edilebilirlik puanları, YFZ içermeyen negatif kontrole benzer bulunmuştur. Köftelere yüksek düzeylerde (%3.0, 4.5 ve 6.0) YFZ ilavesi, depolama süresince pH, lipit oksidasyonu, renk farklılıkları ve mikrobiyal gelişmeyi stabilize etmiştir. Böylece minimum düzeyde bileşimsel ve duyusal değişikliklerle sığır köftelerinin raf ömrünü uzatmak için %4.5 düzeyinde YFZ ilavesi önerilebilir.
Anahtar kelimeler: Sığır köftesi, yer fıstığı zarı, kalite değerlendirmesi, depolama stabilitesi

*Corresponding author / Yazışmalardan sorumlu yazar
: sturhan@omu.edu.tr : (+90) 362 312 1919/1503 : (+90) 362 457 6034

Şule Bıyık; ORCID no: 0000-0003-2406-6111
Sadettin Turhan; ORCID no: 0000-0002-3510-4382

INTRODUCTION

Lipid oxidation and microbial growth are the major reasons for the quality loss and shelf-life reduction in meat products during cold storage. The growth of microorganisms in meat products causes spoilage or foodborne diseases while lipid oxidation adversely affects the color, flavor, texture, and nutritional value of these products (Fernandez-Lopez et al., 2005; Altuntas and Turhan, 2013). The latter can also lead to the formation of potentially toxic oxidation products (Tang et al., 2001; Altuntas and Turhan, 2013). Meat products such as beef patties and hamburgers are more susceptible to microbial and oxidative changes since they are produced from minced meat. Mincing of meat disrupts the integrity of the muscle membrane and increases the surface area that promotes lipid oxidation and microbial growth in stored meat products. Also, these products usually show a rather high-fat content which makes them susceptible to oxidative changes (Danowska-Oziewicz and Kurp, 2017). Although synthetic additives have been widely used in the meat industry to overcome these problems, the trend is to decrease their use because of the toxicity and carcinogenicity of such chemical additives (Juntachote et al., 2006).

The recent decades, there has been a global trend toward using by-products obtained from the agro-industry as natural antioxidants and antimicrobials in foods. One of them, peanut skin (PS), is produced as a by-product of the peanut processing industry. PS is the pink-red layer that covers peanuts and is the primary residue of peanut processing, which represents less than 3% of peanut weight (Lorenzo et al., 2018). PS is traditionally consumed as part of peanuts in many areas of the world without adverse effects and would qualify as a GRAS product (Yu et al., 2010). However, this by-product has limited applications in the industry due to its low commercial value (Lorenzo et al., 2018). Recent research has shown that extracts of PSs are an excellent source of phenolic compounds such as proanthocyanidins and other flavonoids, which are responsible for antioxidant and antimicrobial activities (Yu et al., 2006, 2010; Munekata et al., 2016; Calomeni et al., 2017). PSs are also rich in dietary fibre and potentially other health-promoting compounds. The total dietary fibre accounts for ~45% weight of the roasted PS, of which roughly 2.2% is soluble fibre (Shimizu-Ibuka et al., 2009). In this context, the antioxidant and antimicrobial effects of PS extracts have been studied by some researchers in meat and poultry products. For example, O'Keefe and Wang (2006) reported that PS methanol extract at 200 ppm level prevented lipid oxidation but did not affect the instrumental color, aroma, cooking loss, and microbial growth in cooked ground beef during 14 days of refrigerated storage. However, these authors observed that PS extract levels higher than 400 ppm (600 and 800 ppm) reduced the luminosity, redness, and yellowness of cooked ground beef. Likewise, Yu et al. (2010) observed that the use of PS extract in the raw and cooked ground beef displayed a high effect on the inhibition of lipid oxidation but relatively a low effect on antimicrobial activity during 12 days of refrigerated storage. In the study performed by Munekata et al. (2015), an aqueous extract obtained from PS inhibited the lipid oxidation and prevented the loss of redness in cooked chicken patties during 15 days of refrigerated storage. In another study, 200 ppm of PS extract in raw sheep patties packaged in a modified atmosphere (80% O_2 - 20% CO_2) reduced the redness loss and changes in sensory attributes, prevented lipid oxidation but did not affect the microbial growth during refrigerated storage (Munekata et al., 2016).

As seen in the examples above, although there are few studies on the use of PS extract in meat and poultry products, there is no information about the effect of direct use of this by-product on the quality and shelf life of meat products. The direct use of the PS may increase the shelf life of the product due to the loss of some antioxidative and antimicrobial compounds during the extraction process and enrich the dietary fibre content of the product. In addition, in order to recover bioactive compounds from plant by-products, solvents (eg. methanol) are commonly used, which in many cases can be toxic. Therefore, this study aimed to assess the effect of direct use of PS on the quality

(proximate composition, water holding capacity, texture, and sensory attributes) and storage stability (pH, TBARS, color, and microbial load) of beef patties during cold storage (4 °C).

MATERIAL AND METHOD

Materials

The minced beef (64.33% moisture, 21.55% protein, 11.81% fat and 1.01% ash), beef fat (17.43% moisture, 78.13% fat), and peanut (*Arachis hypogaea* L.) skin (6.54% moisture, 8.48% protein, 12.03% fat and 23.58% ash) were used in the preparation of beef patties, and minced beef and beef fat were purchased from a butcher shop. PS produced as a byproduct of the roasting process of peanuts were obtained from a local nuts company and used in the powder form after being ground with a blender (Waring-8011ES, USA) and passed through a 0.5 μm sieve. Butylated hydroxyl toluene (BHT) was purchased from Sigma-Aldrich (St. Louis, MO, USA). Unless otherwise stated, all chemicals used were of analytical grade.

Determination of total phenolic content and antioxidant activity of PS

Extraction procedure

The extraction of phenolic compounds was carried out according to the procedure explained by Guliyeva and Turhan (2021). Firstly, 5 g of PS was mixed with 20 mL of 80% methanol aqueous solution and submitted to ultrasound for 15 min. Next, the mixture was left in the dark at room temperature for 12 h and filtrated through filter paper (Whatman No. 1, Maidstone, UK). The obtained extract was used for the total phenolic content and antioxidant activity determinations.

Total phenolic content

The total phenolic content of PS was determined using the Folin-Ciocalteu method, as described by Singleton and Rossi (1965). Briefly, the diluted extract was mixed with Folin-Ciocalteau reagent and left at room temperature for 5 min. Then, sodium carbonate was added to the mixture and left in dark at room temperature for 2 h. The absorbance of the mixture was measured with a spectrophotometer (Helios gamma, Thermo Spectronic, Madison, WI) at 760 nm against a blank reagent. The quantity of total phenolic content in the PS was calculated as mg gallic acid equivalent (GAE) per g PS.

2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity of PS was measured according to Nakajima et al. (2004) with a slight modification. Briefly, 50 μL of the diluted extract was added to 1 mL of DPPH methanol solution (100 μM) and left to stand for 1 h at room temperature followed by absorbance measurement of the resulting solution at 517 nm using a spectrophotometer. The DPPH scavenging activity was calculated by the following equation:

$$DPPH\ scavenging\ activity\ (\%) = \frac{Ac-As}{Ac}\ x\ 100 \qquad (1)$$

where Ac is the absorbance of the control (DPPH solution with methanol) and As is the absorbance of the sample. A Trolox standard curve was produced and the antioxidant activity was then calculated as mmol Trolox equivalent (TE) per g PS.

Ferric reducing antioxidant power (FRAP)

The ferric reducing antioxidant power (FRAP) assay of PS was performed according to the methodology, described by Gao et al. (2000). Briefly, 50 μL of the diluted extract was mixed with 0.95 mL ferric-2,4,6-tripyridil-s-triazine (TPTZ) reagent (which was done by mixing 300 mM acetate buffer, pH 3.6, 10 mM TPTZ in 40 mM HCl and 20 mM $FeCl_3$ at the ratio 10:1:1). Then, the sample absorbance was read at 593 nm after 30 min incubation at room temperature using a spectrophotometer. A Trolox standard curve was produced and antioxidant power was then calculated as mmol TE per g PS.

Preparation of beef patties

Six different batches of beef patties were manufactured in Ondokuz Mayis University, Meat and Meat Products Laboratory (Samsun, Turkey) as follows: 1) CON, negative control (78.5% minced beef + 20% beef fat + 1.5% salt); 2) BHT, positive control (78.5% minced beef + 20% beef fat + 1.5% salt + 0.01% BHT); 3) PS15

(77% minced beef + 20% beef fat + 1.5% salt + 1.5% PS); 4) PS30 (75.5% minced beef + 20% beef fat + 1.5% salt + 3.0% PS); 5) PS45 (74% minced beef + 20% beef fat + 1.5% salt + 4.5% PS); 6) PS60 (72.5% minced beef + 20% beef fat + 1.5% salt + 6.0% PS). All batches were mixed for 10 min to obtain a homogenous mass, weighed into ~30 g portions, and shaped by hand with gloves. The final products with a mean of 50 mm diameter and 10 mm thickness were aerobically packaged in polyamide bags with an oxygen transmission rate of 52.4 $cm^3/m^2/24$ h at 1 atm and 23 °C and stored at 4 ± 1 °C home-type refrigerator for 9 days. Samples were randomly selected for analysis at the evaluation periods. Proximate composition, water holding capacity (WHC), texture profile analysis (TPA) and sensory attributes of samples were evaluated on 1 day of storage. The pH, thiobarbituric acid reactive substances (TBARS), color and microbial growth were analyzed on days 1, 3, 6, and 9 of storage.

Determination of proximate composition and water holding capacity

The proximate composition (moisture (950.46), protein (981.10), fat (960.39), and ash (920.153)) of the minced beef, beef fat, PS, and beef patties were determined using the official standard method (AOAC, 2000).

The water holding capacity (WHC) of the beef patties was determined using a press technique explained by Öztan and Vural (1993) with a slight modification. Briefly, 1.0 g of sample was placed on the filter paper (Whatman No. 1, Maidstone, UK), which was placed between two Plexiglas plates and pressed for 1 h by a 1.0 kg weight. The area of pressed meat and a spread juice was measured, and WHC was calculated by the following equation:

$$WHC = \frac{Meat\ film\ area\ (cm^2)}{Total\ surface\ area\ (cm^2)} \quad (2)$$

Determination of textural properties

Textural properties of the beef patties with a mean of 50 mm diameter and 10 mm thickness were determined according to the methodology, described by Öztürk and Turhan (2020) using a Texture Analyzer (TA-XT Plus, Stable Micro Systems, UK) with a 50 mm aluminum cylindrical probe (model P/50R) and a 2 kg load cell. The patties were compressed twice at a pre-test speed of 2.0 mm/s, a post-test speed of 5.0 mm/s, test speed of 5.0 mm/s, and 5 s between compressions. Values for hardness (N), springiness (mm), cohesiveness, and chewiness (N.mm) were calculated from the curves provided by the equipment.

Evaluation of sensory attributes

Sensory properties (appearance, flavor, juiciness, and tenderness) of the beef patties were evaluated by an experienced panelist group of 10 members from the staff and graduate students of the Department of Food Engineering, Ondokuz Mayis University, Turkey. All sensory work was carried out in the sensory evaluation room under fluorescence lighting. The cooked samples were cooled to room temperature, cut into blocks, randomized, and served to each panelist. The panelists evaluated the samples randomly and after rating each sample, rinsed their mouths with water and waited 1-2 min before evaluating the next sample. Flavor, juiciness, and tenderness evaluations were performed only on cooked samples, while appearance was done on both raw and cooked samples. A 9- point hedonic scale was used to assess appearance and flavor (1 = undesirable to 9 = desirable), and a 9- point descriptive scale to assess juiciness (1 = dry to 9 = juicy) and tenderness (1 = tough to 9 = tender). The overall acceptability was calculated taking into account appearance (raw and cooked), flavor, juiciness, and tenderness (each with 20%) (Turhan et al., 2014).

Determination of pH value and lipid oxidation

For the determination of pH, 5 g of patty sample was homogenized with 50 mL distilled water, and the pH value was measured using a digital pH-meter (Cyberscan PC 510, Singapore) calibrated at pH 4 and 7.

Lipid oxidation was assessed by the distillation method according to Tarladgis et al. (1960) and

the absorbance was measured at 538 nm. The content of thiobarbituric acid-reactive substances (TBARS) was calculated from the standard curve prepared with 1,1,3,3-tetraethoxypropane and expressed as mg malondialdehyde (MDA) per kg sample.

Determination of instrumental color

Instrumental color was measured on the surface of beef patties at room temperature using a colorimeter (Minolta Chronometer CR-400, Japan). Three patties per formulation were randomly selected and five readings were taken from each patty. Color measurement included Hunter *L*, *a*, and *b* parameters, where *L* represents lightness with a scale from 0 (black) to 100 (white), *a* represents redness with a scale from −60 (green) to +60 (red), and *b* represents yellowness with a scale from −60 (blue) to +60 (yellow).

In addition, total color change between respective day and day 1 is calculated as color difference (⊿E) by the following equation:

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2} \quad (3)$$

Determination of microbial quality

For the microbial analysis, 10 g of patty sample was aseptically weighed into a sterile stomacher bag and homogenized with 90 mL of sterile saline solution (NaCl, 0.85%) for 2 min at room temperature using a stomacher to make the initial solution. Other decimal dilutions were prepared from this dilution and the surface plate method was used for enumeration. Enumeration of total viable count (TVC) and psychrotrophic bacteria count (PBC) were determined in Plate Count Agar (PCA, Merck) after incubation at 35 °C for 48 h and at 7 °C for 10 d, respectively. The results were log-transformed and expressed as $\log_{10}$ cfu/g.

Statistical analysis

The whole trial was replicated twice (two independent batches), with each replication corresponding to a different production day. For each batch of beef patties, measurements of related traits were carried out in triplicate. The data were analyzed with the SPSS 21 statistical software (IBM, Chicago, IL, USA), and first checked for normal distribution and homogeneity of variances. Data from pH, TBARS, color, and microbiological properties were analyzed using a random block design, considering a mixed linear model including batch and storage as fixed effects and replicate as a random effect. The results of proximate composition, WHC, textural and sensory properties were analyzed by one-way ANOVA, followed by Duncan's multiple range test when the ANOVA was significant (P <0.05). For the sensory analysis, panel day, session number, and panelist number are considered as random effects. All results were expressed as mean value ± standard deviation.

RESULTS AND DISCUSSION

Total phenolic content and antioxidant activity of PS

The phenolic compounds that may occur in all parts of plants are principally responsible for antioxidant activity and can act as reducing agents (free radical terminators), metal chelators, and singlet oxygen quenchers (Shahidi and Naczk, 2004). The total phenolic content determined in PS was 128.26 mg GAE/g while its antioxidant activity as DPPH and FRAP was 417.99 and 41.07 mmol TE/g, respectively (Table 1).

Table 1. Total phenolic content and antioxidant capacity of peanut skin[1]

Parameters	Values
Total phenolic content (mg GAE/g)	128.26±1.15
DPPH[2] scavenging activity (mmol TE/g)	417.99±2.06
FRAP[3] (mmol TE/g)	41.07±0.42

[1]Results are expressed as mean ± standard deviation. Analyses were carried out in triplicate.
[2]DPPH, 2,2-diphenyl-1-picrylhydrazyl, [3]FRAP, ferric reducing antioxidant power.

A similar phenolic content was recorded by Yu et al. (2006) for directly peeled (130.8 mg GAE/g), and roasted PSs (124.3 mg GAE/g) and by Chuenchom et al. (2016) for Spanish (129.0 mg GAE/g) and Valencia PSs (131.94 mg GAE/g). Moreover, numerous authors reported that PS extracts have a strong antioxidant capacity (Yu et

al., 2006; Chuenchom et al., 2016; Calomeni et al., 2017). However, higher phenolic content was recorded by Chuenchom et al. (2016) for Virginia PSs and by Calomeni et al. (2017) in powders produced by spray-drying of PS extracts with 10 and 20% maltodextrin. The phenolic content and antioxidant activity of PS are extremely variable due to different factors such as peanut species, roasting temperature and time, skin removal methods, and solvent types used for extraction (Ma et al., 2014). These findings show that PS could be a good source of natural antioxidants and use as a natural additive in other foods.

Proximate composition and water holding capacity of beef patties with PS

As seen in Table 2, the incorporation of PS at different levels significantly ($P < 0.05$) affected the moisture, protein, and ash content of beef patties whereas its effect on fat content was not significant ($P > 0.05$).

Table 2. Proximate composition, WHC and textural properties of beef patties containing different levels of peanut skin[1]

Parameters	Batches					
	CON[3]	BHT[4]	PS15[5]	PS30[6]	PS45[7]	PS60[8]
Moisture (%)	55.10±1.52^{ab}	56.65±1.78^{a}	54.12±1.50^{b}	53.30±1.19^{bc}	51.72±1.50^{c}	48.47±1.48^{d}
Protein (%)	18.45±0.42^{a}	18.39±0.52^{a}	17.96±0.57^{ab}	17.99±0.64^{ab}	17.27±0.21^{bc}	16.94±0.45^{c}
Fat (%)	23.65±1.88^{a}	21.86±1.10^{a}	22.85±1.76^{a}	22.95±1.77^{a}	22.81±1.37^{a}	20.75±1.42^{a}
Ash (%)	2.40±0.04^{e}	2.42±0.05^{e}	2.87±0.09^{d}	3.19±0.09^{c}	3.60±0.05^{b}	3.99±0.16^{a}
WHC[2]	0.62±0.02^{cd}	0.58±0.01^{d}	0.60±0.05^{cd}	0.66±0.03^{bc}	0.69±0.03^{b}	0.76±0.05^{a}
Hardness (N)	114.82±16.32^{b}	119.64±15.04^{b}	133.36±10.97^{ab}	135.25±17.18^{ab}	169.93±23.63^{ab}	189.49±28.12^{a}
Springiness (mm)	0.86±0.07^{a}	0.78±0.09^{a}	0.85±0.03^{a}	0.77±0.07^{a}	0.77±0.14^{a}	0.74±0.08^{a}
Cohesiveness	0.42±0.04^{a}	0.49±0.10^{a}	0.44±0.08^{a}	0.46±0.10^{a}	0.62±0.05^{a}	0.57±0.05^{a}
Chewiness (N.mm)	40.84±5.27^{c}	44.46±4.44^{c}	49.89±2.96^{bc}	45.76±3.24^{c}	70.81±15.43^{ab}	78.26±10.12^{a}

[1]Results are expressed as mean ± standard deviation. The trial was conducted in duplicate. Analyses were carried out in triplicate. a-e: Means not sharing a common superscript in a row are significantly different at $P < 0.05$ as assessed by Duncan's multiple range test, [2]WHC: water holding capacity, [3]CON: negative control, [4]BHT: positive control with 0.01% BHT, [5]PS15: 1.5% peanut skin, [6]PS30: 3.0% peanut skin, [7]PS45: 4.5% peanut skin, [8]PS60, 6.0% peanut skin.

The moisture and protein content of patties gradually decreased with an increase in PS level, but the ash content increased. The decrease in moisture content could be attributed to the decrease in red meat content and the increase in total solids contents following the addition of PS. Similarly, Turhan et al. (2005) reported a decrease in the moisture content of beef burgers formulated with hazelnut pellicle. Also, Yılmaz (2005) indicated that an increase in wheat bran decreased the moisture content of meatballs. The decrease in protein content could result from the low protein content (8.48%) of PS. Bilek and Turhan (2009) determined a similar decreasing trend in protein content in raw beef patties formulated with different levels of flaxseed flour. Moreover, Aykin Dinçer et al. (2018) observed a concomitant decrease in protein content in meatballs formulated with retrograded flour. The increase in ash content could be attributable to the high ash content (23.58%) of PS. Similar results were also obtained by Bilek and Turhan (2009) in beef patties with added flaxseed flour, and by Öztürk and Turhan (2020) in beef meatballs containing pumpkin seed kernel flour.

The incorporation of PS at different levels significantly ($P < 0.05$) affected the WHC of beef patties and it gradually increased with more PS addition (Table 2). This positive effect could be attributed to the high dietary fiber content of PS. It was reported that PSs contain 42.8-54.7% dietary fiber (Ma et al., 2014), and dietary fibers have the ability to keep the moisture in the matrix (Serdaroğlu et al., 2018). Similar to our results, Serdaroğlu et al. (2018) reported that the addition of dried pumpkin pulp and seed improved the WHC of beef patties.

Textural properties of beef patties with PS

As seen in Table 2, the addition of PS to beef patties significantly (P <0.05) affected the hardness and chewiness whereas its effect on springiness and cohesiveness was not significant (P >0.05). A progressive increase in the PS level increased both the hardness and chewiness values of beef patties. This increase was significant in only 6.0% PS addition for hardness, while it was significant in 4.5% and 6.0% PS addition for chewiness. These results might be due to the decrease moisture content of beef patties (Table 2) with increased levels of PS. Namely, a higher amount of PS may contribute to higher dry matter content which therefore resulted in beef patties with greater hardness and chewiness, particularly in beef patties PS45 and PS60. This was supported by Aykin Dinçer et al. (2018) who observed that the high dry matter content of retrograded flour may increase both the hardness and chewiness of the meatball. Similarly, Ran et al. (2020) reported that with increase *Perilla* seed, the hardness and chewiness of *Perilla* meatballs increased or remained high due to the high solid matter content of *Perilla* seed.

Sensory attributes of beef patties with PS

The addition of PS to beef patties significantly (P <0.05) affected the appearance (raw and cooked), juiciness, and overall acceptability whereas its effect on flavor and tenderness was not significant (P >0.05) (Fig. 1).

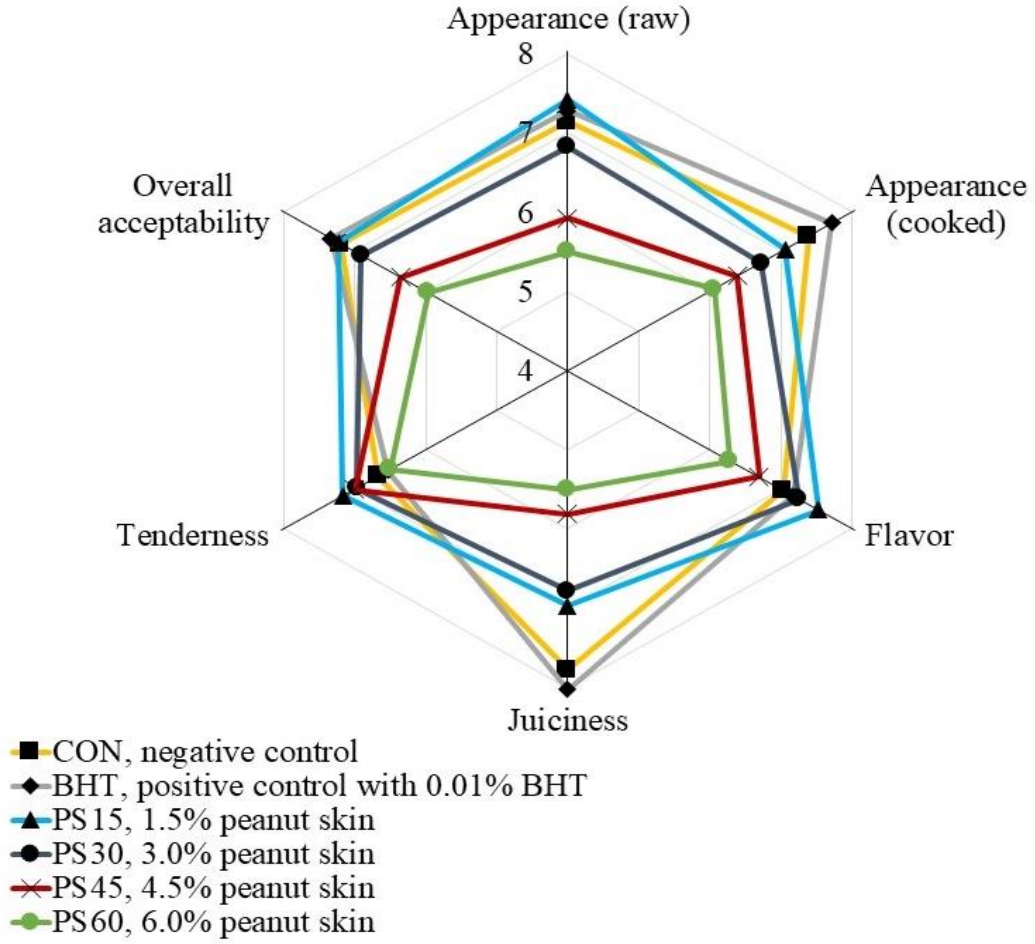

Figure 1. Sensory scores of beef patties containing different levels of peanut skin

Generally, the highest appearance, juiciness, and overall acceptability scores were observed for the negative (CON) and positive control patties (BHT), and the sensory scores decreased with more PS addition (P <0.05). However, the incorporation of PS to beef patties at a level up to 4.5% did not affect the appearance and overall acceptability compared to CON. The incorporation of PS to beef patties at 6.0% level resulted in a brown-red color and this state was probably regarded by panelists as less likable. Finally, the beef patties with 6.0% PS showed the lowest juiciness scores, which agrees with the lower moisture content and the higher hardness values of beef patties (Table 2). Such negative effects of the use of non-meat ingredients at high concentrations on the sensory properties of comminuted meat products were reported by Turhan et al. (2005) in low-fat beef burgers with hazelnut pellicle, and by Yılmaz (2005) in low-fat meatballs with added wheat bran.

pH and TBARS values of beef patties with PS during storage

As seen in Table 3, the initial pH values of beef patty samples ranged from 6.16 to 6.27 and the differences between pH values of samples were not significantly different (P >0.05). Except for PS60 samples, pH values of other meatball samples did not change until the 3rd day of storage (P >0.05) but gradually increased after 3 days of storage. Except for the initial day, on the other days of storage, PS addition to beef patties significantly (P <0.05) decreased the pH values. During storage, the rate of pH increase was significantly higher (P <0.05) in BHT, CON, and PS15 samples than PS30, PS45, and PS60 samples. On day 9 of storage, the highest pH values were observed in BHT and CON samples, followed by the PS15 sample, and the lowest value was observed in PS60 sample (P <0.05). Consequently, the addition of PS significantly enhanced the pH stability of the formulated patties simultaneously with the level of PS suggesting the protective role of PS against spoilage microorganisms. The increase in pH during storage may be attributed to the accumulation of protein decomposition products due to the bacterial action in stored patties (Danowska-Oziewicz and Kurp, 2017; Turhan et al., 2017). Similarly, Turhan et al. (2017) reported a significant increase in the pH of meatballs with and without bee pollen during the storage period. Moreover, Ikhlas et al. (2012) reported an increase in the pH value in *Cosmos caudatus*, *Polygonum minus*, and BHT treated quail meatballs during the refrigeration storage.

Table 3. Changes in pH and TBARS values of beef patties containing different levels of peanut skin during storage at 4 °C[1]

Parameters	Batches	Storage period (days)			
		1	3	6	9
pH	CON[3]	6.27±0.05^{ar}	6.24±0.05^{br}	6.72±0.05^{bq}	7.20±0.06^{ap}
	BHT[4]	6.25±0.05^{ar}	6.33±0.04^{ar}	6.85±0.08^{aq}	7.29±0.04^{ap}
	PS15[5]	6.25±0.04^{ar}	6.22±0.05^{br}	6.67±0.03^{bcq}	6.99±0.07^{bp}
	PS30[6]	6.19±0.03^{ar}	6.13±0.04^{cr}	6.55±0.09^{dq}	6.79±0.08^{cp}
	PS45[7]	6.21±0.18^{ar}	6.08±0.03^{cdr}	6.58±0.05^{cdq}	6.83±0.09^{cp}
	PS60[8]	6.16±0.14^{ar}	6.02±0.07^{ds}	6.40±0.08^{eq}	6.65±0.04^{dp}
TBARS[2] (mg MDA/kg)	CON[3]	1.91±0.12^{aq}	2.30±0.08^{ap}	2.48±0.13^{ap}	2.38±0.11^{ap}
	BHT[4]	0.44±0.06^{bq}	0.56±0.06^{bp}	0.63±0.04^{bp}	0.62±0.05^{bp}
	PS15[5]	0.42±0.06^{bp}	0.46±0.07^{cp}	0.49±0.07^{cp}	0.48±0.08^{cp}
	PS30[6]	0.47±0.04^{bp}	0.47±0.06^{cp}	0.52±0.06^{cp}	0.55±0.06^{bcp}
	PS45[7]	0.42±0.04^{bp}	0.44±0.04^{cp}	0.47±0.08^{cp}	0.47±0.04^{cp}
	PS60[8]	0.47±0.05^{bp}	0.44±0.02^{cp}	0.51±0.05^{cp}	0.49±0.08^{cp}

[1]Results are expressed as mean ± standard deviation. The trial was conducted in duplicate. Analyses were carried out in triplicate. a-e: Means not sharing a common superscript in a column are significantly different at P <0.05 as assessed by Duncan's multiple range test. p-s: Means not sharing a common superscript in a row are significantly different at P <0.05 as assessed by Duncan's multiple range test, [2]TBARS: thiobarbituric acid-reactive substances,

[3]CON: negative control, [4]BHT: positive control with 0.01% BHT, [5]PS15: 1.5% peanut skin, [6]PS30: 3.0% peanut skin, [7]PS45: 4.5% peanut skin, [8]PS60: 6.0% peanut skin.

The addition of PS showed a significant (P <0.05) effect on TBARS of beef patty samples (Table 3). The highest TBARS was obtained in negative control samples (CON) at all storage days; however, patties added with BHT and PS revealed a noticeable decrease in TBARS value compared to the CON samples. The TBARS values for the CON and patties added with BHT increased significantly (P <0.05) with the advancement of the storage period, while non-significant (P >0.05) changes in TBARS values were noticed for beef patties formulated with PS at the different concentration for all storage days. On day 3 of storage, the TBARS value (2.30 mg MDA/kg sample) of the negative control patties was higher than the limit (2.0 mg MDA/kg), which could be considered as a threshold for the acceptability of oxidized beef (Campo et al., 2006). However, the TBARS values (0.47 to 0.62 mg MDA/kg sample) of the positive control (BHT) and all patties containing PS were within the acceptable limit even at the end of storage, indicating the significant antioxidant effect of PS on the patties. This effect can be explained by the phenolic compounds present in the PS such as proanthocyanidins and other flavonoids (Munekata et al., 2016). Such antioxidant effect was in agreement with DPPH and FRAP assays (Table 1), indicating the activity of phenolic compounds in PS on prevention of lipids oxidation. The phenolic compounds can act as reducing agents (free radical terminators), metal chelators, and singlet oxygen quenchers, thus forming a stable product (Shahidi and Naczk, 2004). Similar findings on the reduction of lipid oxidation in meat and poultry products treated with PS extract was also reported by various researchers. For example, O'Keefe and Wang (2006) observed that PS methanol extract at 400 ppm level dramatically reduced TBARS values of cooked ground beef during the period of the 14-day storage. Similarly, Yu et al. (2010) reported that the addition of PS extract to raw ground beef before cooking significantly inhibited the formation of TBARS in cooked ground beef during the refrigerated storage, and PS extract at concentration 0.06% was as effective as BHA/BHT at 0.02% in inhibiting lipid oxidation. In another study, Munekata et al. (2015) presented similar results in cooked chicken patties treated with an aqueous extract (3%) obtained from PS during 15 days of refrigerated storage. In addition, Munekata et al. (2016) indicated that raw sheep patties treated with PS extract at concentration of 1000 ppm showed a lower level of lipid oxidation as compared to control in modified atmosphere packaging condition (80% O_2 + 20% CO_2) during refrigerated storage.

As seen in Table 3, the TBARS level of samples treated with PS was lower than those treated with BHT; this difference was especially significant (P <0.05) on day 3, 6 and 9 of storage period. Similar to our results, it is also reported by some researchers that the possibility of applying PS extract as substitutes for synthetic additives, since they are able to delay oxidative reactions in lipids in a similar or more effective way than their synthetic counterparts. For example, Yu et al. (2010) indicated that the addition of PS extract at concentrations of 0.06% and higher to raw ground beef was as effective as 0.02% BHA/BHT based on measured level of TBARS value in cooked ground beef during refrigerated storage. Similarly, Munekata et al. (2016) showed that in raw sheep patties, the antioxidant potential of PS extract is comparable to that of BHT. Therefore, the present study results indicate that PS can be considered as natural antioxidant to prevent lipid oxidation in meat and meat products.

Instrumental color parameters of beef patties with PS during storage

The addition of PS showed a significant (P <0.05) effect on L values of beef patty samples (Table 4). As seen in Table 4, the incorporation of different levels of PS to beef patties reduced the lightness (L value) of formulated patties compared to the controls (CON and BHT), and lightness values further reduced with increasing PS concentration (P <0.05). Thus, the beef patties formulated with more PS became darker in color compared to the control patties. This effect is probably a consequence of the lower moisture content when PS was added since moisture is related to lightness values (Zhang et al., 2020). Also, this effect could be attributed to the natural color of PS, ranging from light brown to deep red. Similarly, Munekata

et al. (2015) reported that the addition of the PS extract to the chicken patties caused a slight darkening that resulted in lower *L* values compared to the control samples over the storage time. However, non-significant ($P > 0.05$) changes in *L* values were noticed for all-beef patties with the advancement of the storage period.

Table 4. Changes in color parameters of beef patties containing different levels of peanut skin during storage at 4 °C[1]

Parameters	Batches	Storage period (days)			
		1	3	6	9
L[2]	CON[6]	43.39±3.15^{ap}	40.96±1.57^{ap}	43.40±1.22^{ap}	43.36±1.81^{ap}
	BHT[7]	42.90±1.97^{ap}	42.00±0.43^{ap}	42.59±1.72^{ap}	44.54±3.16^{ap}
	PS15[8]	39.42±1.86^{bp}	38.11±1.67^{bp}	37.98±1.74^{bp}	38.79±2.72^{bp}
	PS30[9]	35.63±1.01^{cp}	35.65±1.69^{cp}	35.41±0.63^{cp}	36.81±2.64^{bcp}
	PS45[10]	33.47±0.54^{dp}	34.54±1.06^{cdp}	34.57±0.62^{cdp}	34.83±1.55^{cdp}
	PS60[11]	32.60±0.84^{dp}	33.34±0.96^{dp}	33.24±0.57^{dp}	33.24±0.63^{dp}
a[3]	CON[6]	10.62±0.92^{bpq}	8.62±1.42^{bq}	9.50±2.66^{apq}	11.09±1.79^{ap}
	BHT[7]	12.27±1.15^{ap}	10.42±1.61^{ap}	10.85±1.77^{ap}	11.77±1.25^{ap}
	PS15[8]	8.68±0.27^{cp}	6.91±1.13^{cq}	7.11±1.26^{bq}	6.98±0.76^{bq}
	PS30[9]	7.87±0.48^{cdp}	6.47±0.35^{cq}	6.81±0.88^{bq}	6.17±0.62^{bq}
	PS45[10]	7.90±0.59^{cdp}	6.34±0.17^{cq}	6.09±0.53^{bq}	6.73±0.66^{bq}
	PS60[11]	7.27±0.43^{dp}	6.17±0.18^{cq}	5.77±0.20^{br}	6.26±0.12^{bq}
b[4]	CON[6]	8.51±0.32^{ap}	7.97±1.49^{ap}	7.60±2.15^{apq}	7.52±1.78^{aq}
	BHT[7]	8.58±0.85^{ap}	7.87±1.11^{apq}	6.64±1.39^{aq}	6.81±1.31^{aq}
	PS15[8]	7.91±0.40^{abp}	7.22±0.81^{apq}	6.14±1.00^{aqr}	5.92±1.17^{ar}
	PS30[9]	7.48±0.49^{bp}	7.26±0.46^{ap}	6.68±0.71^{apq}	6.14±1.12^{aq}
	PS45[10]	7.38±0.51^{bp}	7.45±0.31^{ap}	7.10±0.43^{apq}	6.78±0.49^{aq}
	PS60[11]	7.40±0.51^{bpq}	7.55±0.28^{ap}	7.01±0.32^{aq}	7.03±0.40^{aq}
Δ*E*[5]	CON[6]	-	5.32±1.46^{ap}	4.57±0.92^{ap}	3.03±0.87^{aq}
	BHT[7]	-	3.59±1.44^{bp}	4.01±1.26^{abp}	3.23±0.94^{ap}
	PS15[8]	-	3.25±1.26^{bcp}	3.27±0.68^{bcp}	3.38±0.68^{ap}
	PS30[9]	-	1.75±0.83^{dq}	1.78±0.78^{dq}	3.21±0.86^{ap}
	PS45[10]	-	2.12±1.06^{cdp}	2.32±0.73^{cdp}	2.54±0.61^{abp}
	PS60[11]	-	1.90±0.75^{cdp}	2.13±0.36^{dp}	1.79±0.54^{bp}

[1]Results are expressed as mean ± standard deviation. The trial was conducted in duplicate. Analyses were carried out in triplicate. a-d: Means not sharing a common superscript in a column are significantly different at $P < 0.05$ as assessed by Duncan's multiple range test. p-r: Means not sharing a common superscript in a row are significantly different at $P < 0.05$ as assessed by Duncan's multiple range test, [2]*L*: lightness, [3]*a*: redness, [4]*b*: yellowness, [5]Δ*E*: color difference, [6]CON: negative control, [7]BHT: positive control with 0.01% BHT, [8]PS15: 1.5% peanut skin, [9]PS30: 3.0% peanut skin, [10]PS45: 4.5% peanut skin, [11]PS60: 6.0% peanut skin.

At all storage periods, significant differences for *a* values were noticed among the batches and the beef patties containing PS at different levels exhibited a lower *a* value than control samples (CON and BHT) and became less red in color (Table 4). As mentioned above, the decline in redness could be attributed to the natural color of PS. Similar observations on the decrease in *a* values of chicken patties incorporated with PS extract were also reported by Munekata et al. (2015). All the treatments except BHT demonstrated a trend of reduction of *a* values from day 1 to day 3 ($P < 0.05$), but then non-significant ($P > 0.05$) changes were noticed for beef patties containing PS. However, there was no change in the redness values of the BHT samples

during the all storage period. The results showed that the incorporation of PS to beef patties inhibited myoglobin oxidation after day 3 and as a result reduced the formation of metmyoglobin. A similar influence of PS extract on redness was also reported by Yu et al. (2010) in ground beef and by Munekata et al. (2015, 2016) in chicken and sheep patties, respectively.

The incorporation of different levels of PS to beef patties (P <0.05) slightly reduced the b values on day 1, while non-significant (P >0.05) changes in b values were noticed for other storage periods (Table 4). This result was similar to those found by Munekata et al. (2015), who reported the addition of PS extract to chicken patties resulted in lower b values than those observed in the control samples. The b values of both PS-formulated and non-formulated beef patties demonstrated a slight reduction trend during the storage period reaching the minimum values on day 9 (P <0.05). A related study indicated a similar trend in sheep patties produced with BHT or PS extract for 20 days at 2 °C (Munekata et al. 2016).

The positive effect observed of PS on the color of beef patties during the storage period is partially supported by the color differences (ΔE). As seen in Table 4, while on days 3 and 6, all beef patties with added PS showed lower ΔE values compared to the control (CON), on day 9, only beef patties with added PS at 6.0% level showed lower ΔE values (P <0.05). Hence, the addition of PS would help preserve the color stability of beef patties under refrigerated conditions. This protective effect on the color of beef patties may influence consumers' purchase decisions. Such positive effects of the use of non-meat ingredients on the color differences were also reported by Prommachart et al. (2020) in beef patties added with black rice water extract during chilled storage.

Microbial quality of beef patties with PS during storage

The addition of PS to beef patties significantly (P <0.05) affected the TVC whereas its effect on the PBC was not significant (Table 5).

Table 5. Changes in microbial quality of beef patties containing different levels of peanut skin during storage at 4 °C[1]

Parameters	Batches	Storage period (days)			
		1	3	6	9
TVC[2] (log cfu/g)	CON[4]	7.32±0.46^{aq}	8.80±0.52^{ap}	9.16±0.31^{abp}	9.42±0.04^{ap}
	BHT[5]	7.37±0.34^{ar}	8.47±0.12^{abq}	9.20±0.28^{abp}	9.49±0.15^{ap}
	PS15[6]	7.39±0.18^{aq}	8.89±0.27^{aq}	9.33±0.09^{ap}	9.32±0.03^{ap}
	PS30[7]	7.30±0.28^{ar}	8.48±0.14^{abq}	8.91±0.41^{bcp}	9.15±0.12^{bp}
	PS45[8]	7.26±0.32^{ar}	8.41±0.26^{abq}	8.91±0.10^{bcp}	9.00±0.16^{bp}
	PS60[9]	7.27±0.55^{ar}	8.15±0.26^{bq}	8.64±0.07^{cp}	8.72±0.04^{cp}
PBC[3] (log cfu/g)	CON[4]	6.94±0.32^{aq}	7.94±0.46^{ap}	8.37±0.55^{ap}	8.78±0.79^{ap}
	BHT[5]	7.14±0.37^{ar}	7.90±0.54^{aqr}	8.38±0.31^{apq}	8.84±0.84^{ap}
	PS15[6]	7.24±0.25^{aq}	8.02±0.65^{ap}	8.44±0.30^{ap}	8.60±0.55^{ap}
	PS30[7]	7.11±0.22^{ar}	7.96±0.55^{aq}	8.55±0.25^{ap}	8.56±0.35^{ap}
	PS45[8]	7.14±0.24^{aq}	7.89±0.36^{apq}	7.95±1.00^{apq}	8.51±0.50^{ap}
	PS60[9]	6.91±0.23^{aq}	7.72±0.16^{ap}	7.88±0.85^{ap}	8.37±0.47^{ap}

[1]Results are expressed as mean ± standard deviation. The trial was conducted in duplicate. Analyses were carried out in triplicate. a-c: Means not sharing a common superscript in a column are significantly different at P <0.05 as assessed by Duncan's multiple range test. p-r: Means not sharing a common superscript in a row are significantly different at P <0.05 as assessed by Duncan's multiple range test, [2]TVC: total viable count, [3]PBC: psychrotrophic bacteria count, [4]CON: negative control, [5]BHT: positive control with 0.01% BHT, [6]PS15: 1.5% peanut skin, [7]PS30: 3.0% peanut skin, [8]PS45: 4.5% peanut skin, [9]PS60: 6.0% peanut skin.

As seen in Table 5, the initial TVC of beef patties ranged from 7.26 to 7.39 cfu/g and the differences between the TVC of samples were not significantly different ($P > 0.05$). The high initial TVC in beef patties can be attributed to the high level of contamination in the PS produced as a byproduct of the roasting process of peanuts. The TVC and PBC showed a significant increase ($P < 0.05$) during the storage period for all batches, however beef patties added with 3.0, 4.5, and 6.0% PS showed lower TVC than CON and BHT samples at the end of the storage period. However, there were no differences ($P > 0.05$) in TVC on days 3 and 6 among CON, PS30, and PS45 batches. The low plate count determined in the beef patties containing high levels of PS could be attributed to the appreciable phenolic compound content of PS. Similarly, Yu et al. (2010) and Munekata et al. (2016) reported that PS extracts delayed microbial growth in raw ground beef stored at 4 °C for 12 days and in sheep patties stored at 2 °C for 20 days, respectively. Thus, high levels of PS may contribute to the increase in the shelf-life of the beef patties.

CONCLUSION

Our findings showed the PS is a rich source of phenolic compounds and has substantial potential as an antioxidant agent. While the addition of 4.5% PS to the beef patties enhanced WHC, it did not adversely affect the hardness and overall acceptability. Also, the addition of PS into beef patties at high concentrations (3.0, 4.5, and 6.0%) improved lipid and microbial stability during 9 days of cold storage. Thus, PS could be used in beef patties at 4.5% concentration to prolong the shelf life with minimal compositional and sensory changes, and this situation could represent a new alternative for the utilization of PS in the food industry.

CONFLICT OF INTEREST

There are no possible conflicts of interest between the authors.

AUTHOR CONTRIBUTION

This study was derived from Şule Bıyık's Master's thesis and Sadettin Turhan contributed as the thesis supervisor in conducting analyzes, statistical analyses of data, writing the article, and writing-review-proofreading-publishing procedures. The Master's thesis student Şule Bıyık 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.

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