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Research Paper / Araştırma Makalesi

Effects of Red Grape (*Vitis Vinifera* L.) Pomace Powder on Physicochemical and Textural Properties of Sucuk

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ABSTRACT

This study aimed to evaluate the effect of grape pomace powder as a natural antioxidant on the quality characteristics of sucuk samples. Grape pomace powder was added to the sucuk doughs at various concentrations (0, 1, 2, and 3%), and sucuk fermentation was carried out under controlled conditions. The study investigated the effects of grape pomace powder on the chemical composition, total phenolic content, antioxidant activity, texture profile, and color characteristics of the sucuk samples. Results showed a significant impact ($P<0.05$) of grape pomace powder incorporation on the fat, protein, pH, color, total phenolic content, and antioxidant activity of the samples. All color values and pH levels decreased as the amount of grape pomace powder increased. In contrast, total phenolic content and antioxidant activity values increased in direct proportion to the amount of grape pomace powder. According to these results, grape pomace powder has the potential to be used as a natural antioxidant in sucuk production.

Keywords: Sucuk, Grape pomace, Waste, Value added product, Natural antioxidant

Kırmızı Üzüm (*Vitis Vinifera* L.) Posası Tozunun Sucuğun Fizikokimyasal ve Tekstürel Özellikleri Üzerine Etkisi

ÖZ

Bu çalışmada doğal bir antioksidan olan üzüm posası tozunun sucuk örneklerinin kalite özelliklerine etkisinin değerlendirilmesi amaçlanmıştır. Bu amaçla üzüm posası tozu sucuk hamurlarına çeşitli konsantrasyonlarda (%0, 1, 2 ve 3) eklenmiş ve sucuk fermantasyonu kontrollü koşullar altında gerçekleştirilmiştir. Üzüm posası tozunun sucuk örneklerinin kimyasal bileşimi, toplam fenolik madde miktarı, antioksidan aktivite, tekstür ve renk analizleri üzerindeki etkisi araştırılmıştır. Sonuçlar üzüm posası tozu ilavesinin örneklerin yağ, protein, pH, renk, toplam fenolik madde miktarı ve antioksidan aktivitesi üzerinde önemli bir etkisinin olduğunu göstermiştir ($P<0.05$). Üzüm çekirdeği tozu miktarı arttıkça tüm renk değerleri ve pH azalmıştır. Buna karşılık toplam fenolik madde miktarı ve antioksidan aktivite değerleri üzüm çekirdeği tozu miktarıyla doğru orantılı olarak artmıştır. Çalışmada elde edilen sonuçlara göre, üzüm çekirdeği tozunun sucuk üretiminde doğal bir antioksidan olarak kullanım potansiyeline sahip olduğu düşünülmektedir.

Anahtar Kelimeler: Sucuk, Üzüm posası, Atık, Katma değerli ürün, Doğal antioksidan

INTRODUCTION

In recent years, concerns about the consumption of certain foods have escalated due to studies exploring the connections between dietary habits and health issues [1]. The necessity to address consumers' concerns and to make processed foods more beneficial to health has led to the emergence of innovative practices in the food

industry [2, 3]. Among these innovative practices are enhancing the nutritional value of food, strengthening dietary fiber content, and replacing synthetic additives with natural ingredients in production [2]. In this context, research focusing on the utilization of natural plant sources with high phenolic compound content in food formulations has gained prominence in the literature [4-7]. Due to their high content of bioactive compounds and their positive effects on health, grape pomace, which is among these plant sources, can be utilized as a functional ingredient in today's context [8, 9]. Grape pomace, consisting of skins, pulp, and seeds, can account for up to 20% of the weight of processed grapes [10]. The generated grape pomace poses a significant disposal challenge for the viticulture industry. However, due to its phenolic compounds, it attracts considerable attention in the literature as it provides an economic recycling output [11, 12].

Fermented meat products are popular worldwide and sucuk is one of the most consumed fermented meat products in Türkiye [13, 14]. However, meat products are highly susceptible to spoilage due to their rich nutrient content and perishable nature. Therefore, if they are not properly handled and preserved, they can deteriorate and pose a potential public health risks [15]. Recently, studies have focused on extending the shelf life of sucuk production by using nutrient-preserving and enhancing additives while maintaining quality [16, 17]. The bioactive composition of grape pomace includes anthocyanins, flavanols, and phenolic acids, which can extend the shelf life of meat products by inhibiting microbial growth and delaying oxidative processes responsible for the deterioration of sensory and nutritional quality [18]. Furthermore, effective utilization of grape pomace is reported not only to expand relevant industries but also to increase economic benefits by reducing environmental pollution [19].

Upon reviewing the literature, it has been observed that there are a limited number of studies investigating the use of grape pomace powder in the food industry. Additionally, no studies have been found to assess the effects of grape pomace powder on quality characteristics of sucuk. Therefore, the aim of this study was to determine the effect of grape pomace, which is rich in dietary fiber, minerals, and polyphenols (such as proanthocyanidins, flavonoids, phenolic acids, and stilbens) as a natural source of antioxidants on physiochemical and textural properties of sucuk and to present an innovative approach in terms of waste utilization and environmental sensitivity.

MATERIALS and METHODS

Materials

The grape pomace (*Vitis vinifera* L. ssp. *vinifera*) was obtained from the Manisa Viticulture Research Institute (Manisa, Türkiye). Fresh lean beef, beef tail fat, spices and natural cases (D:38 mm, air dired bovine small intestine) used in sucuk production were obtained from local market in Manisa, Türkiye. The other chemicals were supplied from Sigma Aldrich, St. Louis, USA.

Production of Grape Pomace Powder

The grape pomace was subjected to a drying process involving washing and cleaning, followed by drying in a tray dryer at 50°C with an air velocity of 1.5 m/s until it reached a moisture content of 16-18%. The dried pomace was pulverized into powder form by grinding it three times for 15 seconds at 5000 rpm using a blade grinder (Retsch, GM200, Germany) to increase the surface area. The powdered pomace was then sieved using a 100-micron mesh sieve, and the particle sizes were standardized.

Sucuk Formulation and Preparation

Four different groups of sucuk production were conducted to determine the chemical composition, total phenolic content, antioxidant activity, texture profile and color values of sucuks with varying levels of added grape pomace powder. Preliminary experiments were conducted to determine the appropriate grape pomace powder concentration for preserving and enhancing quality characteristics of sucuk. In the previous studies, it was investigated that the addition of grape by-products in the range of 0.75-3.0% had potential usage by enhancing the oxidative and microbial quality of meat products without negatively affecting sensorial quality [20–22]. Carrapiso et al. [23] concluded that 3% grape pomace with a detrimental effect on some sensory characteristics of dry-cured sausages. In addition, Sanchez-Alonso et al. [24] evaluated that fish samples with 4% of grape by-products were not well accepted by semi-trained panelists. So in this study, the grape pomace powder was used up to 3% concentration. The experimental groups consisted of sucuk samples without added grape pomace powder (Control), sucuk samples containing 1% grape pomace powder (GPP1), sucuk samples containing 2% grape pomace powder (GPP2), and sucuk samples containing 3% grape pomace powder (GPP3). The formulation used in sucuk production are presented in Table 1.

The sucuk production flow chart is shown in Figure 1. Fresh lean beef (*Musculus semitendinosus*) as boneless round and tallow fat was purchased from a commercial manufacturer and refrigerated at 4°C during preparation. The production of sucuk was carried out in the Manisa Celal Bayar University Food Engineering Department Meat Science and Technology Laboratory according to the traditional method by Kayaardı and Gök [25]. Other ingredients were supplied from local markets in Manisa, Türkiye. Each sample group was weighed to contain 85% beef meat and 15% beef tallow fat. The other ingredients were added per kg of fresh lean beef and tallow fat mixture, as shown in Table 1. The freshly obtained meat was cut into small pieces and mixed with spices and grape pomace powder according to the experimental design. All the sucuk batches were refrigerated at 4°C overnight. The sucuk mixtures were ground in a grinding machine through a 3-mm grid (Tefal, France) with beef tallow fat and stuffed into air-dried natural casings (D:38 mm) from bovine small intestine. The casings were soaked in a 5% lactic acid solution for 20 minutes before filling. The sucuks were fermented in a controlled cabinet

(Nüve, Turkey) and ripened under the following conditions: 0-3 days at 90% RH, 22°C, and 1.0 m/s air velocity; 4-7 days at 85% RH, 20°C, and 0.5 m/s air velocity; and 7-10 days 80% RH, 18°C, and 0.5 m/s air velocity. During fermentation and ripening, pH monitoring was conducted on sucuk samples. The fermentation and ripening were terminated when the pH reached 4.8. After ripening, all samples were subjected to physicochemical ve textural analysis.

Table 1. Formulations of sucuks

Ingredients	Control*	GPP1	GPP2	GPP3
Beef (g)	850	850	850	850
Beef tallow fat (g)	150	150	150	150
Salt (g)	20	20	20	20
Sugar (g)	4	4	4	4
Garlic (g)	11	11	11	11
Red pepper (g)	12	12	12	12
Cumin (g)	10	10	10	10
Black pepper (g)	8	8	8	8
Allspice (g)	2.5	2.5	2.5	2.5
$NaNO_2$ (ppm)	100	100	100	100
$NaNO_3$ (ppm)	150	150	150	150
Grape pomace powder (g)	0	10	20	30

*Control: sucuk samples without added grape pomace powder (control); GPP1: sucuk samples containing 1% grape pomace powder; GPP2: sucuk samples containing 2% grape pomace powder; GPP3: sucuk samples containing 3% grape pomace powder

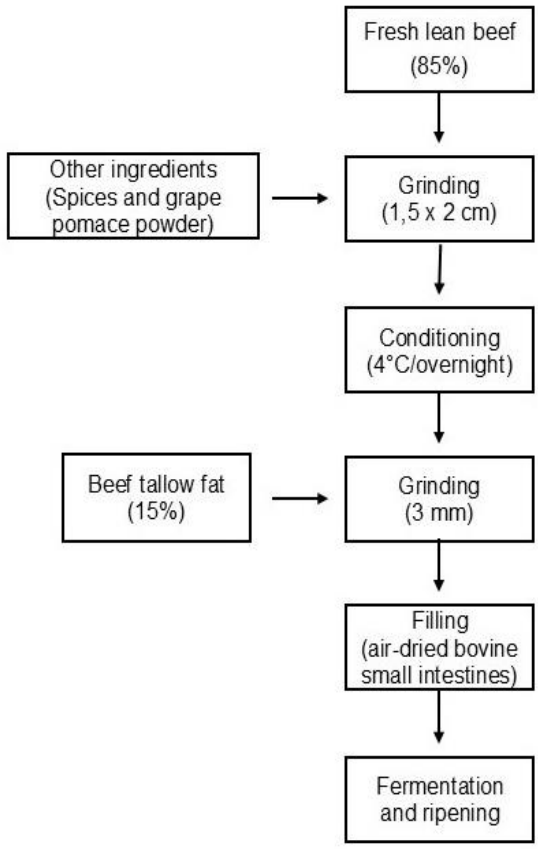


Figure 1. Sucuk production flow chart

Proximate Composition

The sucuk samples were analyzed for moisture (method 934.01), ash (method 942.05), fat (920.39) and protein (method 968.06) contents according to AOAC (2007) standards [26].

pH

The pH values of the samples were determined using a digital pH meter model pH 730 (WTW, Weilheim, Germany) and standardized with appropriate buffers. Measurements were taken from five different regions of the samples. The pH meter probe was immersed in the sample and allowed to stabilize until the value on the display remained constant. The average of five measurements was recorded as the pH value [27].

Color

The color values of the samples (CIE *L*, a*, b**) were determined using a colorimeter Minolta Chromameter CR-5 model (Konica-Minolta Camera Co. Ltd., Osaka, Japan). Evaluation was conducted based on the *L** (darkness-lightness), *a** (redness-greenness), and *b** (yellowness-blueness) color parameters using the CIELAB system. The samples were unpacked and allowed to rest for 10 minutes before color measurements were taken. Five readings were taken from five different regions for each sample [25]. The total color differences in color reading values were calculated as reported by Savanovic et al. [28]. The color values of the control group without added grape pomace powder were used as the reference for calculating ΔE^* in the sample groups containing grape pomace powder at various concentrations.

Total Phenolic Content and Antioxidant Activity

Extractions Procedure for Total Phenolic Content and Antioxidant Activity Assays

Samples were prepared following a modification of the method outlined by Pritchard et al. [29]. Five grams of sucuk samples were taken, and then 50 mL of distilled water was added to the samples, which were subsequently homogenized using an Ultraturrax

(WiseThis HG-15D, Daihan Scientific Co., Seoul, Korea). After that, centrifugation was performed at 4100 rpm at 20°C to transfer the upper phase to a volumetric flask. The same process was repeated twice for the residue. The collected upper phases were combined and brought up to 100 mL with distilled water. The upper phase was filtered and kept at -18°C until analysis.

Total Phenolic Content

The total phenolic content of the samples was determined according to the Folin-Ciocalteu method, modified by Kucuker et al. [30] based on the method developed by Singleton & Rossi [31]. One milliliter of the sample extract obtained through the extraction process was mixed with 0.5 mL of 10% Folin-Ciocalteu's phenol solution and vortexed for 15 seconds. The mixture was then left in the dark at room temperature for 5 minutes. After this period, 1.5 mL of 7.5% Na_2CO_3 solution was added to the mixture, and the sample solution was left in the dark at room temperature for an additional 60 minutes. Subsequently, the absorbance of the resulting color was measured at 760 nm using a Multiskan Go Microplate Spectrophotometer (Thermo Scientific, USA). The results were calculated based on the gallic acid standard curve, and the total phenolic content was determined by substituting the absorbance values obtained from the gallic acid standard curve into the linear regression equation. The total phenolic content is expressed as gallic acid equivalent (GAE) using the gallic acid (0.1 mg/mL) calibration curve.

Antioxidant Activity

The DPPH radical scavenging activity of the sucuk samples was determined according to the method described by Brand-Williams et al. [32] and Singh et al. [33]. Briefly, 100 µL of sample was mixed with 2 mL of 0.1 mM DPPH (1,1-diphenyl-2-picrylhydrazyl) solution in tubes. The tubes were thoroughly mixed and left in the dark at room temperature for 30 minutes. After incubation, the absorbance values against the blank were read at 517 nm using a Multiskan Go Microplate Spectrophotometer (Thermo Scientific, USA), and the results were calculated using the following equation:

$$\text{Total antioxidant activity (\%)} = (1 - A_{sample}/A_{control}) \times 100$$

Where A_{sample}= is the absorbance after addition of test sample (DPPH solution with test sample) and $A_{control}$= is the absorbance of the control (DPPH• solution without test sample).

Texture Profile Analysis

Texture profile analysis (TPA) of samples was conducted using a TA-XT Plus Texture Analyzer (Stable Micro Systems, England). Samples were sliced to a thickness of 0.5 mm and analyzed at room temperature. A 5 kg load cell was used in the experiments and the samples were compressed to 50% of their original height using a cylindrical probe with a diameter of 38 mm. The sample was positioned under the probe, which moved downwards at a constant speed of 2.0 $mm.s^{-1}$ during the pre-test and test phases, and 5.0 $mm.s^{-1}$ during the post-test phase. A 5-second interval was provided between the two compression cycles. The TPA parameters, including hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness were determined following the method described by Mochizuki [34] The measurements of each sample were replicated at least six times. All textural analyses were performed using Texture Exponent software version 4.0.9.0 (Stable Microsystems Ltd., Surrey, England).

Statistical Analyses and Experimental Design

The overall procedure carried out for sucuk manufacture was replicated twice by producing two separate batches on different days. Total of four independent formulations (Control, GPP1, GPP2, GPP3) were created within one replication. For each replicated sample, all experiments were performed three times. The experimental data were statistically evaluated by using the SPSS Version 24.0. One-way analysis of variance (ANOVA) was used to compare the effects of different treatments between groups. Means were compared at 5% significance level ($P<0.05$) by Duncan's multiple range test and the data were reported as the means ± standard errors.

RESULTS and DISCUSSION

Proximate Composition

The proximate composition (moisture, ash, fat and protein) of sucuk samples containing red grape pomace powder is presented in Table 2. The moisture content of the control group was found to be 38.79, but the others varied between 36.32% and 41.02%. The significant differences in moisture content were determined between the GPP1 and GPP2 samples ($P<0.05$), which did not differ from the control group ($P>0.05$). The total ash, fat and protein content of the samples was determined to be between 3.42-3.50%; 21.79-24.34% and 19.17-22.04%, respectively. The effects of grape pomace powder on fat and protein contents of sucuk were found to be significant ($P<0.05$). The fat content was similar in the control, GPP1 and GPP3, while GPP2 samples had significantly lower fat content compared to the control group ($P<0.05$). The incorporation of grape pomace powder also led to significant changes in the protein contents of samples. All treatments had significantly lower protein content than control group ($P<0.05$). The Turkish Food Codex (2019) specifies that sucuk should contain at least 16% total meat protein by weight, with the moisture to protein ratio not exceeding 2.5, and the fat to protein ratio also below 2.5 [35]. Assessing these regulations, it was found that all samples had a protein content exceeding 16%, with an average moisture-to-protein ratio of 1.97 and an average fat-to-protein ratio of 1.16. Therefore, our results indicated that all samples complied with the criteria outlined by those standards.

Table 2. Proximate composition and pH values of sucuk samples

Sample group*	Moisture (%)**	Ash (%)	Fat (%)	Protein (%)	pH
Control	38.79±0.77^{ab***}	3.49±0.09	24.10±0.77^{a}	22.04±0.05^{a}	4.94±0.006^{a}
GPP1	41.02±2.50^{a}	3.42±0.04	24.34±0.83^{a}	19.17±0.03^{c}	4.75±0.03^{b}
GPP2	36.32±0.89^{b}	3.50±0.31	21.79±0.49^{b}	19.41±0.05^{b}	4.81±0.03^{b}
GPP3	40.69±1.67^{ab}	3.41±0.09	22.19±1.01^{ab}	19.33±0.01^{b}	4.79±0.005^{b}

*Control: sucuk samples without grape pomace powder addition; GPP1: sucuk samples fortified with 1% grape pomace powder; GPP2: sucuk samples fortified with 2% grape pomace powder; GPP3: sucuk samples fortified with 3% grape pomace powder; **The values were expressed as mean ± SD.***a-d: different letters within a same column indicate the effect of treatment and differ significantly (P<0.05).

pH

The mean pH values of sucuk samples incorporated with varying levels of grape pomace powder are shown in Table 2. The pH values of the samples ranged between 4.75-4.94. The incorporation of grape pomace powder resulted in significant changes in the pH values of sucuk samples (P<0.05). The control group exhibited the highest pH value compared to the other tested groups. The pH values of the samples containing grape pomace powder were significantly lower than the control group (P<0.05). This result might be due to the acidic and polyphenolic compounds present in grape pomace powder. Moreover, the pH values of all treatments were compliant with The Turkish Food Codex (2019) of a maximum 5.4 value of below for sucuk. Similarly, the pH values of frankfurters reduced from 6.12 to 5.97 with the addition of starch-sodium caseinate and grape seed flour [35]. On the contrary, Kurt [21]reported that the pH values of sucuk samples increased with the inclusion of grape seed extract during ripening and storage. These variations may be attributed to the distinct characteristics of the ingredients added to the formulation and the type of the product.

Instrumental Color Analysis

Color is a crucial visual attribute through which consumers often assess the quality and desirability of a product. Table 3 illustrates the instrumental color parameters (*L**, *a**, *b**) of sucuk samples. A significant reduction in *L**, *a**, *b** values was observed upon the addition of grape pomace powder in sucuk samples (P<0.05). The incorporation of grape pomace powder resulted in a darkening of the samples, with a greater browning degree observed at higher concentrations of grape pomace powder. Similarly, both the *a** and *b** values of the samples decreased with increasing amounts of grape pomace powder. This decrease in the color values may be due to the masking of the product's natural color caused by the addition of grape pomace powder. Riazi et al. [22] also reported similar decreases in *L**, *a**, parameters for beef sausage samples fortified with grape pomace powder at various concentration (1% and 2%) compared to control group. The decreases in *L** values can be attributed to the antioxidant effect of grape pomace powder, which is rich in variety of phenolic compounds that have free radical scavenging properties [36].

Table 3. Color values of sucuk samples

Sample group^{+}	*L**$^{+}$	*a**	*b**	*ΔE**
Control	51.78±0.26^{a+++}	16.55±0.55^{a}	23.63±0.27^{a}	0
GPP1	50.64±1.07^{ab}	15.36±0.24^{b}	20.46±0.62^{b}	3.60±1.07^{b}
GPP2	47.00±0.58^{c}	13.57±0.16^{c}	18.97±0.45^{c}	7.32±0.38^{a}
GPP3	49.37±0.73^{b}	12.89±0.19^{d}	18.96±0.08^{c}	6.41±0.23^{a}

$^{+}$Control: sucuk samples without grape pomace powder addition; GPP1: sucuk samples fortified with 1% grape pomace powder; GPP2: sucuk samples fortified with 2% grape pomace powder; GPP3: sucuk samples fortified with 3% grape pomace powder; $^{++}$The values were expressed as mean ± SD. $^{+++}$a-d: different letters within a same column indicate the effect of treatment and differ significantly (P<0.05).

The total color differences (*ΔE**) is typically considered an indicator of differences noticeable to the human eye. The findings indicated that the use of grape pomace powder at concentration 2% and 3% in sucuk formulation significantly impacted total color differences compared to its use at a concentration of 1% (P<0.05). According to the International Lighting Commission (CIE), a total color difference between 0 and 2 is undetectable and a difference between 2 and 3.5 can be recognized by an inexperienced observer, while a value exceeding 3.5 indicates a noticeable color deviation for the observer (P<0.05) [28]. Thus, in the present study the total color differences of all samples were significantly recognizable by the observer (P<0.05). The smallest color changes were determined in the GPP1 group while the largest color changes were observed in GPP2 group. The results suggest that sucuk samples containing grape pomace powder were more dissimilar in color, compared to control group. It could be due to anthocyanins present in the red grape pomace [37].

Texture Profile Analysis

The texture profile results of the sample groups are presented in Table 4. The addition of grape pomace powder did not affect the hardness, adhesiveness, springiness, gumminess, or chewiness values of the samples statistically (P>0.05).

The hardness values of samples increased and the chewiness values of the samples decreased with the addition of grape pomace powder compared to the control group, but these changes were not statistically different (P>0.05). Grape pomace powder had a high dry matter content, so this may be the reason for the increased hardness values [38]. Similarly, Alencar et al. [39] found that the addition of grape skin flour to beef burgers increased the hardness values of the samples compared to the control group (P<0.05). Also, Pereira et al. [38] had reported that addition of grape pomace to

hamburger patties increased the hardness values compared to control samples (P<0.05). They concluded that the dietary fiber content of grape pomace powder had contributed to the increase of the hardness values.

Table 4. Texture profile analyze values of sucuk samples

Sample group*	Hardness (N)**	Adhesiveness (N.s)	Springiness	Cohesiveness	Gumminess	Chewiness
Control	95.93±15.77	-0.72±0.26	0.76±0.08^{a***}	0.68±0.10	66.60±20.3	51.46±19.32
GPP1	138.67±13.91	-1.14±0.34	0.66±0.11^{ab}	0.56±0.09	76.37±5.97	50.89±10.94
GPP2	103.50±58.62	-0.76±0.15	0.55±0.07^{b}	0.64±0.02	66.74±39.78	38.57±27.57
GPP3	107.89±12.92	-0.77±0.01	0.53±0.04^{b}	0.62±0.05	66.79±8.44	35.38±2.14

*Control: sucuk samples without grape pomace powder addition; GPP1: sucuk samples fortified with 1% grape pomace powder; GPP2: sucuk samples fortified with 2% grape pomace powder; GPP3: sucuk samples fortified with 3% grape pomace powder; **The values were expressed as mean ± SD.; ***a-d: different letters within a same column indicate the effect of treatment and differ significantly (P<0.05).

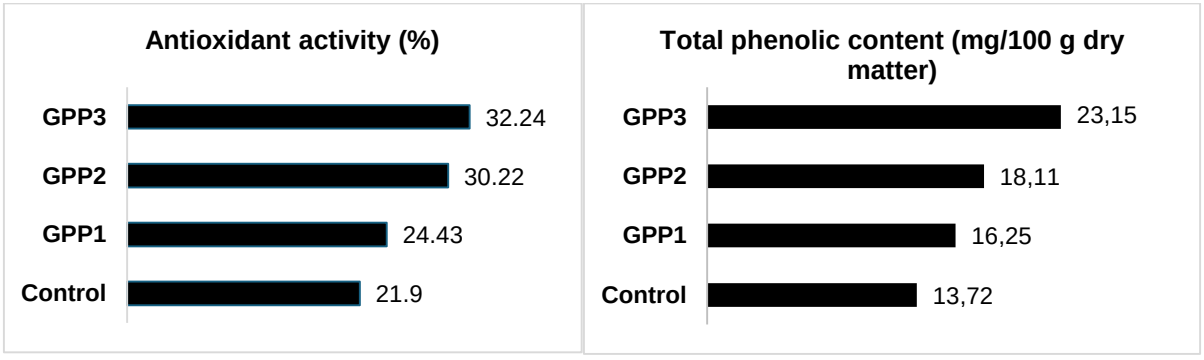
Total Phenolic Content and Antioxidant Activity

As can be seen in Table 5, the total phenolic content of the samples was found to be between 13.72-23.15 mg/100 g dry matter. All sample groups had higher phenolic content than control group. It is clear from the results that as the level of grape pomace powder increased, the phenolic content increased. The statistical differences between the sample groups were significant (P < 0.05). The antioxidant activities of the samples were found to be between 21.90-32.24 %. All sample groups fortified with grape pomace powder had higher antioxidant activities than the control group. GPP3 samples had the highest antioxidant activity, but the difference between GPP3 and GPP2, and also the difference between control and GPP1 samples, was not statistically different (P>0.05).

Table 5. Total phenolic content and antioxidant activity of sucuk samples

Sample group*	Total phenolic content (mg/100g dry matter)**	Antioxidant activity (%)
Control	13,72±0.35^{d***}	21.90±1.44^{b}
GPP1	16.25±0.78^{c}	24.43±0.36^{b}
GPP2	18.11±0.09^{b}	30.22±1.83^{a}
GPP3	23.15±0.67^{a}	32.24±2.1^{a}

*Control: Sucuk samples without grape pomace powder addition; GPP1: Sucuk samples fortified with 1% grape pomace powder; GPP2: Sucuk samples fortified with 2% grape pomace powder; GPP3: Sucuk samples fortified with 3% grape pomace powder; **The values were expressed as mean±SD.; ***a-d: Different letters within a same column indicate the effect of treatment and differ significantly (P<0.05).



(a) (b)

Figure 2. (a) Antioxidant activity(%), (b) Total phenolic content of the sucuk samples (mg/100 g dry matter) (Control: sucuk samples without grape pomace powder addition; GPP1: sucuk samples fortified with 1% grape pomace powder; GPP2: sucuk samples fortified with 2% grape pomace powder; GPP3: sucuk samples fortified with 3% grape pomace powder)

As mentioned in several studies, grape and grape by-products with high levels of flavanols, phenolic acids, anthocyanins and tannins had antioxidant and antimicrobial effects on meat and meat products [18, 21, 40–52]. It is thought that the increase in grape pomace powder addition rate increases antioxidant activity and phenolic content in direct proportion [22]. In this study, the antioxidant activity of grape pomace powder was found to be 98.30±0.06 (%). This result is in agreement with Zhu et al. [53] who found the antioxidant activity of wine grape pomace 96.0 % and lower than the DPPH scavenging activity of grape pomace powder investigated by Hayta et

al. [54]. In the study conducted by Amin & Edris [55], it was found that incorporation of minced meat with different levels of grape seed extract (50, 200 and 1000 ppm) showed increasing antioxidant activity (%) with the increased grape seed extract level. Carrapiso et al. [23] noted that the grape pomace added in the levels of 0.5% and 3% provided 3.83 and 22.9 mg phenols 100 g−1 of fresh batter, respectively. Riazi et al. [22] found total phenol content of dry cured sausages between 62-74 mg gallic acid/100 g sample. It was noted that he lowest levels were for control samples, while the highest contents were for grape pomace-added (1% and 2%, w/w) ones. The values were higher than the phenolic content of the samples in our study but the increase in phenolic content by the addition rate of grape pomace powder is in agreement with this study.

CONCLUSION

In conclusion, the results of the present study revealed that incorporating grape pomace powder is a viable option as a natural additive in sucuk, improving total phenolic content and antioxidant activity while maintaining quality characteristics in terms of chemical composition and pH without negatively impacting textural properties. The addition of grape pomace powder resulted in a significant increase in the total phenolic and antioxidant activities of the samples, leading to the conclusion that these types of foods may have nutritionally beneficial properties ($P<0.05$). In addition, GPP-treated samples showed significantly lower pH and color values than those of the control ($P<0.05$). However, grape pomace powder addition had a noticeable effect on sucuk color as perceived by the human eye. The decrease in the color values of the samples could be due to the darker color of the grape pomace powder ingredient. Based on the promising results, especially in the nutritional aspects, future research could focus on the studying consumer acceptance as well as microbiological and oxidative changes during storage.

REFERENCES

[1] Rather, S.A., Ahmad Masoodi, F.A., Akhter, R., Rather, J.A., Shiekh, K.A. (2016). Advances in use of natural antioxidants as food additives for improving the oxidative stability of meat Products. *Madridge Journal of Food Technology*, 1(1), 10–17.

[2] Gutierrez-Gonzalez, V., Rivero-Perez, M.D., Gerardi, G., Muñiz, P., González-SanJose, M.L., Jaime, I., Cavia-Saiz, M. (2023). Influence of the packaging systems on the phenolic profile and antioxidant properties of wine pomace used as seasoning in chicken meat. *Food Chemistry,* 427, 136625.

[3] Nuriler, T., Uyarcan, M. (2024). Fonksiyonel et ürünlerinin üretiminde probiyotik, prebiyotik ve sinbiyotik kullanımına yönelik yeni eğilimler. *Gıda,* 49(1), 25–38.

[4] Vaithiyanathan, S., Naveena, B.M., Muthukumar, M., Girish, P.S., Kondaiah, N. (2011). Effect of dipping in pomegranate (*Punica granatum*) fruit juice phenolic solution on the shelf life of chicken meat under refrigerated storage (4°C). *Meat Science,* 88, 409–14.

[5] Li, W., Zhang, X., He, Z., Chen, Y., Li, Z., Meng, T., Li, Y., Cao, Y. (2020). In vitro and in vivo antioxidant activity of eucalyptus leaf polyphenols extract and its effect on chicken meat quality and cecum microbiota. *Food Research International,* 136, 109302.

[6] Vo, G.T., Liu, Z., Chou, O., Zhong, B., Barrow, C.J., Dunshea, F.R., Suleria, H.A.R. (2022). Screening of phenolic compounds in Australian grown grapes and their potential antioxidant activities. *Food Bioscience*, 47, 101644.

[7] Ordaz-Rodríguez, S.B., López-Hernández, L.H., Jesus Mendoza-Sánchez, M., Escobar-Ortiz, A., Abadía-García, L., García-Pérez, J., Mendoza-Sanchez, M. (2023). Green extract of pomegranate peel (*Punica granatum L.*) obtained by ultrasound assisted extraction and its preservative properties on raw chicken burgers. *Food and Humanity,* 1, 1046–1054.

[8] Sinrod, A.J.G., Shah, I.M., Surek, E., Barile, D. (2023). Uncovering the promising role of grape pomace as a modulator of the gut microbiome: An in-depth review. *Heliyon*, 9, e20499.

[9] Karantonis, H.C., Tsoupras, A., Moran, D., Zabetakis, I., Nasopoulou, C. (2023). Olive, apple, and grape pomaces with antioxidant and anti-inflammatory bioactivities for functional foods. In Functional Foods and Their Implications for Health Promotion, Edited by I. Zabetakis, A. Tsoupras, R. Lordan, D. Ramji, *Academic Press*, London, p. 131–159.

[10] Demirkol, M., Tarakci, Z. (2018). Effect of grape (*Vitis labrusca L.*) pomace dried by different methods on physicochemical, microbiological and bioactive properties of yoghurt. *LWT-Food Science and Technology*, 97, 770–777.

[11] Sevindik, O., Selli, S. (2016). Üzüm çekirdeklerinin temel biyoaktif bileşenleri. *Çukurova Tarım ve Gıda Bilimleri Dergisi*, 31(2), 9–16.

[12] Barba, F.J., Zhu, Z., Koubaa, M., Sant'Ana, A.S., Orlien, V. (2016). Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: A review. *Trends in Food Science & Technology,* 49, 96–109.

[13] Ergezer, H., Gökçe, R., Elgin, Ş., Akcan, T. (2016). Kızılcık (*Cornus mas L.*) ekstraktı kullanımının sucuk kalite karakteristikleri üzerine etkisi. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 24, 1376–1381.

[14] Dertli, E., Yilmaz, M.T., Tatlisu, N.B., Toker, O.S., Cankurt, H., Sagdic, O. (2016). Effects of in situ exopolysaccharide production and fermentation conditions on physicochemical, microbiological, textural and microstructural properties of Turkish-type fermented sausage (sucuk). *Meat Science*, 121, 156–165.

[15] Aminzare, M., Tajik, H., Aliakbarlu, J., Hashemi, M., Raeisi, M. (2018). Effect of cinnamon essential oil and grape seed extract as functional-natural additives in the production of cooked sausage-impact on microbiological, physicochemical, lipid oxidation and sensory aspects, and fate of

inoculated *Clostridium perfringens*. *Journal of Food Safety,* 38(4), e12459.

[16] Ünal, K, Karakaya, M. (2017). Farklı hayvansal yağlar ilave edilerek üretilen sucukların bazı fizikokimyasal özellikleri üzerine karanfil ve tarçının etkisi. *Tekirdağ Ziraat Fakültesi Dergisi,* 14(03), 55–65.

[17] Kavuşan, H.S., Serdaroğlu, M. (2021). Fermente et ürünlerinde oksidatif değişiklikler ve ürün kalitesi üzerine etkileri. *Gıda,* 46(2), 443-462.

[18] Santos Silva, M.E., Grisi, C.V.B., Silva S.P., Madruga, M.S., Silva, F.A.P (2022). The technological potential of agro-industrial residue from grape pulping (*Vitis* spp.) for application in meat products: A review. *Food Bioscience*, 49, 101877.

[19] Chen, Y., Wen, J., Deng, Z., Pan, X., Xie, X., Peng, C. (2020). Effective utilization of food wastes: Bioactivity of grape seed extraction and its application in food industry. *Journal of Functional Foods,* 73, 104113.

[20] Ryu, K.S., Shim, K.S., Shin, D. (2014). Effect of grape pomace powder addition on TBARS and color of cooked pork sausages during storage. *Korean Journal of Food Science and Animal Resources,* 34, 200-206.

[21] Kurt S. (2016). The effects of grape seed flour on the quality of Turkish dry fermented sausage (Sucuk) during ripening and refrigerated storage. *Korean Journal for Food Science and Animal Resources,* 36(3), 300–308.

[22] Riazi, F., Zeynali, F., Hoseini, E., Behmadi, H.(2016). Effect of dry red grape pomace as a nitrite substitute on the microbiological and physicochemical properties and residual nitrite of dry-cured sausage. *Nutrition and Food Sciences Research*, 3, 37–44.

[23] Carrapiso, A.I., Martín-Mateos, M.J., D'Arrigo, M., Delgado-Adámez, J., Saraiva, J.A., Ramírez-Bernabé, M.R. (2024). High-hydrostatic-pressure-stabilized white grape pomace to improve the oxidative stability of dry-cured sausages ("Salchichón"). *Foods,* 13.

[24] Sánchez-Alonso, I., Solas, M.T., Borderías, A.J. (2007). Physical study of minced fish muscle with a white-grape by-product added as an ingredient. *Journal Food Science*, 72(2), E94-101.

[25] Kayaardi, S., Gök, V. (2003). Effect of replacing beef fat with olive oil on quality characteristics of Turkish soudjouk (sucuk). *Meat Science,* 66, 249-257.

[26] AOAC (2007). Official Methods of Analysis of AOAC. Washington, DC: Association of Official Analytical Chemists.

[27] Söbeli, C., Uyarcan, M., Kayaardı, S. (2021). Pulsed UV-C radiation of beef loin steaks: Effects on microbial inactivation, quality attributes and volatile compounds. *Innovative Food Science & Emerging Technologies*, 67, 102558.

[28] Savanović, D., Grujić, S., Grujić, R., Savanović, J. (2014). Effect of antioxidants on the colour stability of fermented sausage "sucuk" type. *Quality of Life*, 5 (1-2), 19-32.

[29] Pritchard, S.R., Phillips, M., Kailasapathy, K. (2010). Identification of bioactive peptides in commercial Cheddar cheese. *Food Research International*, 43, 1545-1548.

[30] Kucuker, E., Ozturk, B., Celik, S.M., Aksit, H. (2014). Pre-harvest spray application of methyl jasmonate plays an important role in fruit ripening, fruit quality and bioactive compounds of Japanese plums. *Scientia Horticulturae*, 176, 162–169.

[31] Singleton, V.L., Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, 16, 144-158.

[32] Brand-Williams, W., Cuvelier, M.E., Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology,* 28(1), 25–30.

[33] Singh, R.P., Chidambara Murthy, K.N., Jayaprakasha, G.K. (2002). Studies on the antioxidant activity of pomegranate (*Punica granatum*) peel and seed extracts using in vitro models. *Journal of Agricultural and Food Chemistry,* 50(1), 81-86.

[34] Mochizuki, Y. (2001) Texture Profile Analysis. In: Current Protocols in Food Analytical Chemistry, Edited by R.E. Wrolstad, John Wiley & Sons Inc., New York, p. H2.3.1–H.2.3.7.

[35] Turkish Food Codex Regulation (2019). The Comminique on Meat, Prepared Meat Mixtures, and Meat Products, No: 30670, 2018/52. 29.01.2019, *Ministry of Agricultural and Forestry*, Ankara.

[36] Garrido, M.D., Auqui, M., Martí, N., Linares, M.B. (2011). Effect of two different red grape pomace extracts obtained under different extraction systems on meat quality of pork burgers. *LWT - Food Science and Technology*, 44, 2238–2243.

[37] Turcu, R.P., Panaite, T.D., Untea, A.E., Șoica, C., Iuga, M., Mironeasa, S. (2020). Effects of supplementing grape pomace to broilers fed polyunsaturated fatty acids enriched diets on meat quality. *Animals*, 10, 947.

[38] Pereira, A., Lee, H.C., Lammert, R., Wolberg, C., Ma, D., Immoos, C. (2022). Effects of red-wine grape pomace on the quality and sensory attributes of beef hamburger patty. *International Journal of Food Science Technology,* 57(3), 1814–1823.

[39] Alencar M.G., Quadros, C.P., Luna, A.L.L.P., Neto, A.F., Costa, M.M., Queiroz, M.A.Á., Carvalho, F.A.L., Silva Araujo, D.H., Gois, G.C., Anjos Santos, V.L., Silva Filho, J.R.V., Souza Rodrigues, R.T. (2022). Grape skin flour obtained from wine processing as an antioxidant in beef burgers. *Meat Science,* 194, 108963.

[40] Amariei, S., Norocel, L., Pădureţ, S., Gutt, G. (2018). Effect of grape seed flour on the quality of summer salami. *Journal of Food Processing and Preservation*, 42, e13601.

[41] Argade, A., Bishnoi, S., Ahlawat, S.S. (2017). Utilization of wine industry waste (Grape pomace) in processed meat products: A review. *The Pharma Innovation Journal,* 6(12), 297–301.

[42] Bobko, M., Haščík, P., Krocko, M., Trembecká, L., Mendelová, A., Tkáčová, J., Czako, P., Toth, T. (2017). Effect of grape seed extract on quality of raw-cooked meat products. *Potravinarstvo Slovak Journal of Food Sciences*, 11(1), 517-521.

[43] Cilli, L.P., Contini, L.R.F., Sinnecker, P., Lopes, P.S., Andreo, M.A., Neiva, C.R.P., Nascimento, M.S., Yoshida, C.M.P., Venturini, A.C. (2020). Effects of grape pomace flour on quality parameters of salmon burger. *Journal of Food Processing and Preservation,* 44, e14329.

[44] El-Kholie, E.M., Khafagi, M.M., El-Zahraa, F., Dawood, S.A. (2014). Enhancement of beef sausage quality using grape seeds as natural antioxidants. *Journal of Home Economics,* 24(1), 99-117.

[45] Kaur, S., Kumar, S., Bhat, Z.F. (2015). Effect of grape seed extract on the physicochemical and sensory properties of chicken nuggets. *Journal of Meat Science*, 11(1), 57-60.

[46] Kumari, K., Thind, S., Journal R. (2020). Effect of flaxseed flour, grape peel and wheat gluten incorporation levels on the sensory quality of chicken meat patties. *Food Science Research Journal,* 11(1), 8–16.

[47] Kumcuoglu, S., Cagdas, E. (2015). Effects of grape seed powder and whey protein on quality characteristics of chicken nuggets. *Journal of Food Quality,* 38, 83–93.

[48] O'Grady, M.N., Carpenter, R., Lynch, P.B., O'Brien, N.M., Kerry, J.P. (2008). Addition of grape seed extract and bearberry to porcine diets: Influence on quality attributes of raw and cooked pork. *Meat Science,* 78, 438-446.

[49] Özvural, E.B, Vural H. (2011). Grape seed flour is a viable ingredient to improve the nutritional profile and reduce lipid oxidation of frankfurters. *Meat Science,* 88, 179–83.

[50] Reddy, G.V.B., Sen, A.R., Nair, P.N., Reddy, K.S., Reddy, K.K., Kondaiah, N. (2013). Effects of grape seed extract on the oxidative and microbial stability of restructured mutton slices. *Meat Science,* 95, 288–94.

[51] Tremlova, B., Havlova, L., Benes, P., Zemancova, J., Buchtova, H., Tesikova, K., Dordevic, D. (2022). Vegetarian "sausages" with the addition of grape flour. *Applied Sciences,* 12, 2189.

[52] Tuffi, L.C., Longhi, D.A., Hernandes, J.C., Gregório, P.C., Rocha Garcia, C.E. (2021). Grape residue flour as an antioxidant and fiber source in beef meatballs. *British Food Journal,* 123, 2831-2843.

[53] Zhu, F.M., Du, B., Li, J. (2014). Effect of ultrafine grinding on physicochemical and antioxidant properties of dietary fiber from wine grape pomace. *Food Science and Technology International,* 20, 55–62.

[54] Hayta, M., Özuğur, G., Etgü, H., Şeker, I.T. (2014). Effect of grape (*Vitis vinifera* L.) pomace on the quality, total phenolic content and anti-radical activity of bread. *Journal of Food Processing and Preservation*, 38, 980–986.

[55] Amin, R.A., Edris, S.N. (2017) Grape seed extract as natural antioxidant and antibacterial in minced beef. *PSM Biological Research*, 2(2), 89–96.