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Effect of freeze-dried yoghurt powders on the physicochemical, microbial changes, and Texture profiles of Sucuk, a traditional turkish fermented sausage, throughout fermentation

Einfluss von gefriergetrockneten Joghurtpulvern auf die physikalisch-chemischen, mikrobiellen Veränderungen und Texturprofile von Sucuk, einer traditionellen türkischen fermentierten Wurst, während der Fermentation

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Summary

This study investigated the effects of yoghurt powder (YP) on pH, water activity, lactic acid content, color, and microbiological properties of sucuk doughs during the 2 days fermentation period. In addition, proximate compositions, texture and sensory characteristics of sucuk samples that were heat treated after the fermentation period were determined. Three different sucuk formulations were prepared containing C: control (without yoghurt powder); T1: 1.5% yoghurt powder; T2: 3.0% yoghurt powder. The pH and a_w values were found to be in the range of 4.79–5.90 and 0.957–0.971 throughout the fermentation, respectively. The coliform bacteria counts were slightly higher in the control sucuk samples while expectedly *Lactobacillus* spp. numbers were positively correlated with yoghurt powder levels. Addition of yoghurt powder had significant ($P < 0.05$) effects on the hardness, cohesiveness, gumminess, chewiness, and resilience values of samples. In particular, the hardness of the sucuk samples containing 1.5% yoghurt powder were significantly higher compared to control samples ($P < 0.05$). Moreover the addition of yoghurt powders did not cause any sensorial defect. Consequently, 1.5% YP may be a good additive for sucuk production by means of improving some textural characteristics, enhancing *Lactobacillus* spp. counts and acidity, and repressing coliform bacteria.

Keywords: Microbiology, yoghurt powder, Sucuk, texture

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Introduction

One of the most important traditional meat products in Turkey is sucuk. It is produced from a mixture of meat, fat, some spices, garlic, salt, and nitrite. After mixing, they are stuffed into natural or synthetic casings. Sucuk is produced in two steps: fermentation (with or without starter culture) and drying of the sucuk under controlled (climatic) or spontaneous conditions. These stages are known as ripening resulting in the physical, chemical, and microbiological changes in some properties of the sucuk. Texture, color, and flavor of sucuk are also developed during these steps. Nowadays, heat treatment has been combined with the production process to shorten the processing time and achieve a safe final product (Bozkurt and Bayram, 2006; Dalmıs and Soyer, 2008).

Microorganism activity, especially lactic acid bacteria, plays an important role in the fermentation of sucuk. These bacteria provide the characteristic properties of sucuk such as color, smell, texture, and structure by degrading of carbohydrates, protein, and lipid. Starter cultures are widely used today to obtain products of standard quality. Lactic acid bacteria (LAB) are preferably used as a starter culture in sucuk production (Lücke, 2000; Dalmıs and Soyer, 2008; Kaban, 2013; Bilenler et al., 2017). If a starter culture is not used in the production of sucuk, the microorganisms originate from the meat itself and/or from the environment carry out the fermentation so-called ”spontenaous fermentation“ (Gökalp et al., 2010).

Yoghurt is a milk product fermented with lactic acid bacteria which shall be in a viable state, active, and still present in the product through the end of shelf life (CODEX, 2003). Yoghurt is a highly popular fermented dairy product (Sert et al., 2017). It has high nutritional value, and health benefits (Prasanna et al., 2013). Yoghurt powder, produced by drying fresh yoghurt, can be used by the industry as an ingredient for the manufacturing of many food products (Kumar and Mishra, 2004). It also contains lactic acid bacteria and has highly valuable protein contents which are also found in fresh yoghurt (Koc et al., 2010).

Freeze-drying is considered a suitable method for drying heat-sensitive pigments. It is based on dehydration by sublimation of a frozen product and, during this procedure, core materials and matrix solutions are homogenized and then colyophilized, resulting in a dry material (Wilkowska et al., 2016; Yamashita et al., 2017). Freeze-drying is the most important process to dry products containing bacteria while maintaining viability (Kumar and Mishra, 2004; Chávez and Ledeboer, 2007; Koc et al., 2010).

The purpose of the present study was to investigate the usage of different concentrations of freeze-dried yoghurt powder on the sucuk production. Different concentrations of yoghurt powder (0% as control, 1.5% and 3.0%) were added to the sucuk dough. The effects of yoghurt powder on the physicochemical, textural, sensory, and microbiological properties of sucuk were determined during two days fermentation and ready-to-eat sucuk samples.

Material and Methods

Materials

Beef (Angus, 24-months-old) aged 1 day following slaughter and beef fat were obtained as boneless rounds from a local butcher in Konya, Turkey. The meat was grounded through a 3 mm-grid. Spices (NaCl, cumin, red pepper, black pepper, pimento) and additives (garlic, sucrose, $NaNO_2$) were purchased from a local market in Konya.

Yoghurt powder preparation

Yoghurt powders used in this study were obtained by freeze-drying in a pilot-scale freeze-drier (Scanvac, 110-4 PRO, Denmark). Yoghurt samples (3 liters) were placed in trays and frozen at –50°C temperature. A vacuum readout of 0.001 mbar and final shelf temperature of 25°C were used to dry the yoghurt samples. Drying time was 24 to 48 h. The characteristics of the yogurt powder used in this study were as follows: 3.84% moisture, 34.44% protein, 0.50% fat, 7.96% ash, 4.67 for pH value and 0.80% lactic acid content.

Sucuk production

Sucuk production was conducted under factory conditions. Sucuk formulation included 67.5% beef, 24% beef fat, 2% NaCl, 1.75% garlic, 0.25 sucrose, 1% cumin, 2% red pepper, 0.7% black pepper, 0.8% pimento, and 100 ppm sodium nitrite. The meat and fat were minced in a grinder (Arı Makine, Turkey) with a mixture of spices and additives. Three different sucuk doughs were prepared depending on the yoghurt powder addition level; C (control), without yoghurt powder (0.0%); T1, including 1.5% yoghurt powder and T2, including 3.0% yoghurt powder. In the formulation of sucuks manufactured with yoghurt powder, amount of beef fat was reduced accordingly yoghurt powder addition level. Each sucuk dough was stuffed into 32 mm diameter collagen casings. Stuffed sucuk doughs to casings were put into a climatic room under the following conditions: 10 hours at 24°C and 88% relative humidity (RH), 6 hours at 22°C and 90% RH, 8 hours at 20°C and 88% RH, 8 hours at 18°C and 84% RH, and 16 hours at 18°C and 80% RH. Then they were gradually exposed to heat treatment until the core temperature reached to 66–68°C (for 20 minutes) and were cooled immediately to 10°C. The ready-to eat sucuk samples were stored at 4°C until analysis. Sucuk production was carried out with two replications, in 6 kg independent batches (20 sucuks) for each treatment.

Sampling

Sucuk samples were taken after the stuffing process (day 0) and during the fermentation period (before heat treatment) on days 1 and 2. pH, aw, lactic acid, color properties (L*, a* and b*), and microbiological (TMAB, Staphylococcus-Micrococcus, Lactobacillus, Streptococcus, coliform, yeast-mold) analyses were examined on days 0, 1 and 2. Proximate compositions (moisture, protein, fat, and ash) pH, aw, lactic acid, sensory and texture analyses were determined in the ready-to eat sucuk samples (after heat treatment). Samples were randomly selected for each analysis. Analyses were repeated in triplicate for each analysis method.

Proximate composition, pH, water activity and lactic acid analyses

Moisture, protein, ash, and fat (ether-extraction) contents of the sucuk samples were determined by using the standard methods (AOAC., 2000).

pH values of the samples were measured by a pH meter (Mettler, Toledo) according to (Gökalp et al., 2012).

The water activity of the samples (Testo, Germany) was determined in accordance with the method of Troller and Christian (1978).

The lactic acid contents of samples were determined according to AOAC (2000). Lactic acid contents of samples were expressed as lactic acid percentages (lactic acid %).

Determination of color properties

Color measurements were performed by using a chromameter (model CR-400, Konica Minolta, Osaka, Japan) with illuminant D65 (*L*, a*,* and *b** values), 2° observer, 8 mm illumination range, in mode Diffuse/O (CIE, 1976). The measurements were performed by applying three different readings on the exterior surfaces of the samples in each group and on cross-sections of slices taken from every sucuk sample.

Sensory analysis

Sensory analysis of the samples was carried out by ten experienced panelists consisting of staff from the Food Engineering Department at Selcuk University. Before the sensory evaluation, samples were removed from the casings and cut into slices with 0.5 cm thickness and grilled for 1 min each side at 150°C on pre-heated hot plate. Panelists participated in two sessions and for each session, six samples (two pieces for each sample group) were presented to each panelist. Then, samples were served to the panelists who evaluated the color, texture, firmness, flavor, and overall acceptability of the samples. Each panelist scored each sample on a hedonic scale of 1 (worst) to 9 (best). Unsalted bread and water were used to clean and neutralize the palates between each sample. The analysis was repeated twice, and samples were selected randomly (Gökalp et al., 2012).

Texture profile analysis (TPA)

TA-XT plus texture analyzer with a 50 kg load cell was used to determine texture profile analysis of the sucuk samples using a compression test. Sucuk samples were sliced at a 1.5 cm height. Samples were allowed to reach room temperature prior to texture analyses. A 36 mm-diameter cylinder probe with a radiused edge was used to determine the texture measurement applying 50% compression (strain). Hardness (N), adhesiveness (N.s), springiness (mm), cohesiveness, gumminess (N), chewiness (N.mm), and resilience of the samples were measured by a software program (Herrero et al., 2007).

Microbiological analysis

For microbiological analysis, 25 g was aseptically taken from each of the sucuk samples and transferred into sterile pouches containing 225 ml peptone water (0.1%) (Merck, Germany), homogenized by a stomacher (Lab Blender, Seward, London). After homogenization, serial decimal dilutions were made in the same diluent, and 0.1 mL samples of appropriate dilutions were spread on selective agar plates in duplicate. The count of total aerobic mesophilic bacteria was determined on Plate Count Agar (PCA; Merck) incubated at 37°C for 48 h while the count of *Streptococcus thermophilus* was determined by aerobic incubation of culture M17 medium supplemented with 0.5% (wt/vol) lactose (7.2±0.2, Merck KGaA, Darmstadt, Germany) at 37°C. The presumptive *Lactobacillus delbrueckii* ssp. *bulgaricus* counts were calculated by anaerobic incubation on deMan Rogosa Sharpe Agar (MRS) (5.7 ±0.2, Merck KGaA, Darmstadt, Germany) at 37°C for 48 h. *Micrococcus-Staphylococcus* were cultured on Baird Parker Agar (BPA; Merck) incubated at 37°C for 48 h, and Yeast-mould on Potato Dextrose Agar acidified by sterile tartaric acid (10%) (Merck) incubated at 25°C for 5 days. Coliform bacteria were cultured on Violet Red Bile Agar (VRBA; Merck) anaerobic incubated at 37°C for 24 h (Sırıken et al., 2006).

Statistical analyses

Each parameter was tested in triplicate samples with two replications. Proximate composition, pH value, water activity, color, sensory, texture profile, and microbiological properties of the samples were analyzed by two-way Analysis of Variance. Sensory data were analyzed using the generalized linear model procedure. Collected data were subjected to statistical analyses using the MINITAB for Windows Release 16.0. The mean values were analyzed using the Tukey Multiple Comparison Test.

Results and Discussion

pH, a_w, lactic acid and color properties of samples during two days fermentation

Table 1 shows the effects of yoghurt powder addition and fermentation period on pH, aw, lactic acid, *L*, a*,* and *b** values of the samples. The pH values of these samples began to decline at the end of the fermentation (Day 2). Control group had the lowest mean pH (5.25) values (P<0.01). Palamutoglu and Saricoban (2016) have reported the pH values of control sucuk as 5.26. They have also determined the highest pH value as 5.90 at the beginning of the ripening time. These values are the similar as our values (5.90), as seen in Table 1. While the addition of yoghurt powder decreased the water activity value of the sausages, the water activity values of the samples decreased with the progress of fermentation (P<0.01).

The decrease in the pH value of sucuk groups is related to the production of lactic acid. The highest lactic acid content was determined on the 2nd day of fermentation, which caused the lowest pH value. However, addition of yoğurt powder did not affect the lactic acid content of samples (P>0.05)

The effects of the yogurt powder addition on the *L*, a*,* and *b** values of the samples were found not to be significant (P>0.05). As seen in Table 1, redness *(a*)* value increased significantly (P<0.05) from 14.66 to 20.58 during 2

TABLE 1: *Effects of yoghurt powder addition and fermentation time on pH, a_w, lactic acid, color values of samples during two days fermentation.*

Factor	pH	a_w	Lactic acid (%)	*L**	*a**	*b**
Concentration (A)						
C	$5.250±0.591^c$	$0.962±0.019^b$	$1.028±0.465^a$	$44.901±1.161^a$	$18.940±2.873^a$	$16.987±2.456^a$
T1	$5.430±0.527^a$	$0.970±0.006^a$	$1.022±0.366^a$	$45.170±1.529^a$	$18.657±3.710^a$	$16.736±2.247^a$
T2	$5.400±0.385^b$	$0.971±0.005^a$	$1.045±0.318^a$	$43.891±2.308^a$	$19.184±3.684^a$	$17.613±2.216^a$
Significance	**	**	ns	ns	ns	ns
Fermantation period (B)						
0 day	$5.900±0.061^a$	$0.974±0.006^a$	$0.653±0.075^c$	$45.631±0.675^a$	$14.661±0.412^b$	$19.320±1.414^a$
1 day	$5.400±0.158^b$	$0.971±0.003^b$	$0.947±0.029^b$	$43.619±1.606^a$	$20.797±1.903^a$	$16.518±1.545^b$
2 day	$4.790±0.160^c$	$0.957±0.015^c$	$1.495±0.086^a$	$44.718±2.158^a$	$20.577±1.820^a$	$15.498±1.642^b$
Significance	**	**	**	ns	**	**
A x B	**	**	*	ns	*	ns

**(P<0.01), *(P <0.05), ns: not significant, LSMeans ± Standard error. a–c: Mean values followed by different superscripts within the same column indicate a significant difference. C: Control (without yoghurt powder), T1: including 1.5% yoghurt powder, T2: including 3.0% yoghurt powder

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days of fermentation. The increase in *a** values during the first day of fermentation might be due to the formation of nitrosomyoglobin, related to the characteristic red color of this type of meat product (Wirth, 1986). Yellowness *(b*)* value of the sucuk samples decreased significantly (P<0.05). The changes in yellowness values during the fermentation are probably due to the oxygen consumption by microorganisms during their exponential growth phase leading to a decrease in oxymyoglobin which contributes to the value of this color coordinate system (Üren and Babayiğit, 1996; Üren and Babayiğit, 1997). Our results were in agreement with Kayaardı and Gok (2003), Bozkurt and Bayram (2006), Bayram and Bozkurt (2007). Similar results were also obtained by Pérez-Alvarez et al. (1999), who have found that the *b** value of their sausages decreased throughout the fermentation and ripening periods.

TABLE 2: *Proximate composition, lactic acid, pH and a_w values of ready-to-eat sucuk samples.*

Treatment	Moisture (%)	Protein (%)	Fat (%)	Salt (%)	Ash (%)	Lactic acid (%)	pH	a_w
C	44.947±0.27[a]	16.685±0.01[c]	30.200±0.01[a]	2.885±0.007[a]	3.240±0.16[a]	1.410±0.02[ab]	4.705±0.03[ab]	0.945±0.00[c]
T1	44.489±0.16[ab]	17.050±0.01[b]	29.735±0.01[b]	2.775±0.021[b]	3.256±0.05[a]	1.460±0.01[a]	4.625±0.02[b]	0.955±0.00[a]
T2	43.732±0.16[b]	17.110±0.01[a]	29.160±0.04[c]	2.810±0.014[b]	3.140±0.03[a]	1.360±0.01[b]	4.745±0.01[a]	0.949±0.00[b]

Values represent the mean ± standard error. a–c: Mean values followed by different superscripts within the same column indicate a significant difference (P<0.05). C: Control (without yoghurt powder), T1: including 1.5% yoghurt powder, T2: including 3.0% yoghurt powder.

TABLE 3: *The effects of yoghurt powder on textural characteristics of ready-to-sucuks.*

Treatment	Hardness (N)	Adhesiveness (N.s)	Springiness (mm)	Cohesiveness	Gumminess (N)	Chewiness (N.mm)	Resilience
C	295.60±0.90[b]	36.42±3.31[a]	0.80±0.01[a]	0.55±0.00[c]	163.30±1.32[b]	130.10±2.55[b]	0.18±0.00[c]
T1	312.50±0.08[a]	32.13±2.45[a]	0.83±0.00[a]	0.59±0.00[a]	184.70±2.18[a]	152.60±0.64[a]	0.21±0.01[a]
T2	289.70±1.55[c]	29.39±7.55[a]	0.81±0.01[a]	0.58±0.00[b]	167.70±0.55[b]	135.70±1.11[b]	0.20±0.00[b]

C: Control (without yoghurt powder), T1: including 1.5% yoghurt powder, T2: including 3.0% yoghurt powder. a–c: Different uppercase superscript letters show differences between the treatments within the column values (P<0.05).

Proximate composition, lactic acid, pH and a_w values of the ready-to-eat sucuk samples

Moisture, protein, fat, ash, salt, lactic acid, pH, and a_w values of the ready-to-eat sucuks are given in Table 2. Moisture values were found to range from 43.72 to 44.95, and initial moisture contents were between 51.94 and 51.33%. Adding yoghurt powder changed the proximate composition of the final sucuk samples. The highest fat and salt values were determined in the control group. Due to the heat process and fermentation, the final samples yielded lower moisture and water activity but higher protein and salt values. The water activity of the sucuk samples was found as 0.9656 on the stuffing day, but it decreased to 0.955 in the final product. During the fermentation and heating process, the water activity of the sucuk samples decreased. Ercoskun et al. (2010) have found that salt, ash, fat, and protein values of their samples increased during the fermentation as a result of drying. They have also stated that heat treatment led to a significant increase in these values.

Texture profiles of sucuk samples

Desired textural properties of sucuk are being elastic and easily sliceable and not sticking to the knife during slicing (Bozkurt and Erkmen, 2002; Kayaardı and Gok, 2003). Table 3 indicates the effects of adding yoghurt powder on the textural properties of the ready-to-eat sucuk samples. Figure 1 also shows the effects of yogurt powder addition on the texture profile diagrams of samples. The addition of yoghurt powder affected the hardness values of the samples (P<0.05). Hardness values changed in the range of 289.70–312.50 N. As seen in Figure 1, while the group of T2 had the lowest hardness value, the sample containing 1.5% yoghurt powder had the highest hardness value. Bayram and Bozkurt (2007) have reported a negative correlation between moisture content and hardness value of cured meat products. Serra et al. (2005) have observed that the hardness values of the cured ham increased during drying, suggesting that this may be due to proteins becoming closer to each other and new interactions being formed. Herrero et al. (2007) have found the hardness values of chorizo, salchichón, salami, fuet, and mini fuet to be between 100 and 272 N.

Yoghut powder addition did not lead to a significant effect (P>0.05) on the adhesiveness and springiness values of the samples. Adhesiveness and springiness values of the samples were determined to be in the range of 29.39–36.42 g.s and 0.80-0.83 mm, respectively. Bozkurt and Bayram (2006) have also reported similar findings for adhesive-

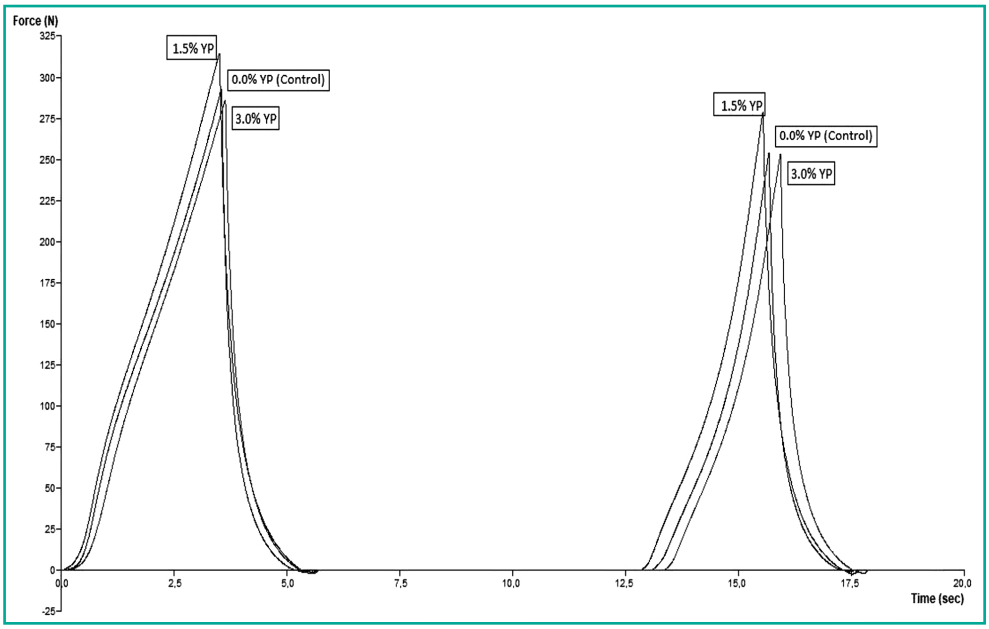

FIGURE 1: *Texture profile diagrams of ready-to-eat sucuk samples.*

ness (9.3 to 92.6 g.s) and springiness (0.65 to 0.82) values of sucuk.

Cohesiveness values changed in the range of 0.55–0.59. The difference between the samples was statistically significant (P<0.05). The highest cohesiveness values were measured for the sucuk sample in the group of T1. Hoz et al. (2004) have determined cohesiveness values between 0.46 and 0.52 in dry fermented sausage. Cohesiveness and resilience of our samples increased by adding 1.5% yoghurt powder.

The difference between gumminess and chewiness values of the samples was statistically significant (P<0.05). It was determined that gumminess and chewiness values of the sucuk samples ranged between 163.30 and 184.70 N and between 130.10 and 152.60 N.mm, respectively. The group of T1 had the highest gumminess and chewiness values. The addition of 3.0% yoghurt powder did not make any change on the gumminess and chewiness values of the samples compared to the C. Addition of yoghurt powder improved the textural charecteristics of sucuk samples. The increase in the gumminess and chewiness values increased the mouthfeel characteristics. Crehan et al. (2000) have determined the chewiness values of frankfurters containing 5%, 12%, and 30% fat to be in the range of 119.9–190.9 N.mm.

Adding YP also improved the resilience of the sucuk samples (P<0.05). The samples containing 1.5% yoghut powder had the highest resilience values. In a study on the effects of black carrot concentrate on the textural properties of Turkish dry-fermented sausage, have determined that resilience values of sucuk samples changed in the range of 0.13–0.20 (Ekici et al. 2015).

Sensory analysis of sucuk samples

Table 4 shows the color, texture, firmness, flavor, and overall acceptability scores of the sucuk samples. Addition of yoghurt powder did not affect the sensorial properties of the sucuk samples compared to the C (P>0.05). Yıldız-Turp and Serdaroglu (2008) have found a decrease in sensory scores when hazelnut oil was added to the sucuk. Yalınkılıç et al. (2012) have reported that adding 2g/100g orange fiber did not significantly affect the appearance, flavor, color, texture, and overall acceptability of samples and that increasing fiber levels negatively affected the sensory acceptability.

Microbial counts of sucuk samples

The microbiological behaviors determined in the fortified samples are shown in Table 5. On the second day of fermentation, TMAB counts were higher than those calculated on the first day of the fermentation period. A gradual increase was observed throughout this fermentation duration but the increment detected from the first day to the second day was not statistically significant. This was in accordance with the findings of Ercoşkun and Özkal (2011), who have reported a sharp increase in TMAB counts after the first day of fermentation and a stable trend until the end of the third day when examining traditional Turkish sausage fermentation kinetics. Gök et al. (2011) have attributed this tendency to the reduction of the high relative humidity in the progress of time. On the other hand, there was no statistical difference in the sucuk samples enriched with YP in different proportions. Consistent with our result, Ekici et al. (2015) have found no change in TMAB counts when the samples were fortified with black carrot concentrates at different levels (0.5, 1, and 2%). Likewise, these results are in agreement with Porcella et al. (2001), who have reported no growth enhancement for TMAB in Argentinian chorizo manufactured with soy protein isolate. Presumptive *Lactobacillus* spp. counts of Turkish sucuk samples fortified with yoghurt powder showed a dramatic increase after the first day of ripening and then slight but not statistically significant increase until the end of the remaining fermentation period. Similar lactic acid bacteria -enumerated with MRS medium- behaviors during the fermentation of traditional Turkish sausage production have been reported by Ercoşkun and Özkal (2011). Besides, Soyer et al. (2005) have reported a rapid increase from the initial fermentation day up to the second day (from about 4.5 to 8.5 log CFU/g) and thereafter, a steady trend was observed for naturally fermented Turkish sausage. As expected, in the current study, micobial counts on MRS medium were positively correlated with yoghurt powder levels, which is probably due to the presumptive *Lactobacillus* spp. which had routinely been used as starter cultures during yoghurt production. *Staphylococcus-Micrococcus* spp. counts showed no statistical variation during the assessed fermentation period, which is in parallel with the findings of Yalınkılıç et al. (2012), who have reported no substantial differences in sucuk samples containing different levels of orange fibers. Also, (Lücke, 1985) has stated that no or slight growth occurred during sucuk fermentation regarding catalase-positive cocci. Sucuk samples containing 1.5% yoghurt powder had significantly higher counts of *Staphylococcus-Micrococcus* spp. compared to C, however, no statistical change was detected between the samples enriched with 1.5 and 3.0% yoghurt powder. This may, therefore, be associated with a considerable increase in presumptive *Lactobacillus*

TABLE 4: *Sensory scores of ready-to-eat sucuk samples.*

Treatment	Color	Texture	Firmness	Flavour	Overall Acceptability
C	5.83±0.62	5.06±0.48	6.06±0.79	6.67±0.57	6.89±0.48
T1	5.72±0.60	5.50±0.57	5.67±0.65	7.17±0.51	7.22±0.47
T2	5.72±0.57	5.56±0.55	6.00±0.63	7.33±0.54	7.11±0.53

Values represent the mean ± standart error. A 9-point hedonic scale was used (9: extremely liked, 5: moderately liked, 1: disliked). C: Control (without yoghurt powder), T1: including 1.5% yoghurt powder, T2: including 3.0% yoghurt powder.

TABLE 5: *The effects of yoghurt powder concentration and fermentation time on microbiological properties of sucuk samples during two days fermentation.*

Factor	Microbial counts (log kob/g)					
	PCA	BPA	MRS	LM17	VRB	PDA
Concentration (A)						
C	7.71±1.98^{a}	4.01±0.57^{b}	6.95±2.18^{c}	7.81±1.84^{a}	1.36±2.11^{a}	1.65±1.98^{a}
T1	7.70±1.77^{a}	4.59±0.24^{a}	7.32±2.25^{b}	7.74±1.95^{a}	1.26±1.97^{b}	1.14±1.81^{a}
T2	7.77±2.04^{a}	4.50±0.34^{a}	7.72±1.79^{a}	7.75±1.98^{a}	1.24±1.93^{b}	1.38±2.13^{a}
Significance	ns	**	**	ns	**	ns
Fermantation period (B)						
0 day	5.24±0.19^{b}	4.54±0.34^{a}	4.66±0.62^{b}	5.29±0.21^{b}	3.88±0.18^{a}	3.86±0.53^{a}
1 day	8.92±0.10^{a}	4.21±0.63^{a}	8.59±0.09^{a}	8.99±0.17^{a}	0.00±0.00^{b}	0.31±0.76^{b}
2 day	9.02±0.17^{a}	4.36±0.38^{a}	8.73± 0.44^{a}	9.02±0.08^{a}	0.00±0.00^{b}	0.00±0.00^{b}
Significance	**	ns	**	**	**	**
A x B	**	*	**	ns	**	ns

** P<0.01, * P<0.05, ns: not significant. LSMeans ± Standard error. C: Control (without yoghurt powder), T1: including 1.5% yoghurt powder, T2: including 3.0% yoghurt powder. a-c: Mean values followed by different superscripts within the same column indicate a significant difference.

spp. counts between the sucuk samples with 1.5 and 3.0% yoghurt powder. In other words, high presumptive *Lactobacillus* spp. counts in yoghurt containing 3% powder may have suppressed *Staphylococcus-Micrococcus* spp. These findings are consistent with the findings of Dalmıs and Soyer (2008), who have reported that *Staphylococcus-Micrococcus* spp. appeared to be significantly influenced by rapid acidification or growth of lactic acid bacteria. Coliform bacteria were found on the first day but were not detected during the remaining days of the fermentation period. This is supported by Kaban (2013), who has stated that the number of *Enterobacteriaceae* species in sucuk decreases with increasing ripening time due to acidification. The coliform bacteria count was slightly lower in sucuk samples fortified with 3% yoghurt powder compared to the other formulations with 1.5% and 0% in line with titratable acidity values, as seen in Table 1. Indeed, Lücke (1985) has reported that acidification led to a significant decrease in the number of *Enterobacteriaceae.* Regarding yeast and mold counts, there were no statistical differences among all treatments, thereby yoghurt powder did not lead to a significant increasing or decreasing effect on the number of yeast and mold of the sucuk samples. Also, throughout the storage, yeast and mold numbers gradually declined and they totally inhibited on the second day of fermentation. These decreases are in contrast with the study of Gök et al. (2011), who have found a small increase at first and then a decrease in yeast and mold counts. In contrast, Bacha et al. (2009) have reported that mold counts were entirely eliminated at 96 h when investigating the microbial dynamics during the fermentation of wakalim, which is a traditional Ethiopian fermented sausage. Our results are in agreement with the findings of Rantsiou et al. (2005), who have examined Italian fermented sausages throughout the fermentation process. These authors have observed that yeast and molds were detected only at day zero and not seen again during the 30 days of fermentation.

Conclusions

The results of the current study indicate that the addition of yoghurt powders changed some physicochemical, textural, and microbiological properties of the sucuk samples. pH values were detected to be low in the sucuk sample with 1.5% yoghurt powder. The coliform bacteria count was slightly higher in the control sucuk samples compared to the other formulations with 1.5% and 3.0% yoghurt powders. The microbial counts on MRS plates in sucuk samples were positively correlated with the additional levels of yoghurt powder, probably due to the normal use of *Lactobacillus* spp. within yoghurt starter culture combinations. Significant changes were observed in the texture profiles of the sucuk samples. The use of yoghurt powder affected the hardness, cohesiveness, gumminess, chewiness, and resilience values of the samples. As a conclusion, yoghurt powder could be suggested in the sucuk formulation to improve its quality parameters without causing any sensorial defect.

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Conflict of Interest

We have no conflict of interest to declare.

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