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The effects of fermentation time on heat treated sucuk (turkish-style dry-fermented sausage)

Einfluss der Fermentationsdauer auf wärmebehandelte Sucuk (türkische, trockengepökelte Rohwurst)

Hüdayi Ercoşkun

Summary

As a result of the meat industry's search for a shorter and safer production method; heat treatment became the most popular production method after a short fermentation in sucuk manufacture. Heat treatment of at least 68 °C is applied in the production of sausage which causes deterioration of quality attributes of the product. The effect of heat treatment at 60 °C for 10 minutes on sucuk attributes was determined during fermentation intervals and after heat treatment, and the properties of the heat treated sucuk samples were compared with the traditional sucuk. Heat treated sucuk was fermented in different fermentation intervals (0, 1, 2, 3, 4, 5 and 6 days). The optimum fermentation time was tried to be determined for the sucuk samples with the desired properties. For traditional sucuk, fermentation continued for nine days. All processes were carried out under commercial and industrial conditions. Heat treatment increased dry matter contents (protein, fat, salt and ash), pH values, and thiobarbituric acid reactive substances values of sucuk in all fermentation intervals. Moreover, heat treatment reduced moisture contents, free fatty acidity values, total viable and lactic acid bacteria, and the counts of *Staphylococcus*/*Micrococcus* and *Enterobacteriaceae*. Heat treatment decreased L*, a* and b* values and decreased residual nitrite, total haem pigment and nitrosomyoglobin amounts but increased nitrozation ratio. With the application of 60 °C for ten minutes of heat treatment, microbial destruction at higher temperatures around 70 °C degrees was reached after the fermentation period of 2 days. In terms of the measured parameters, it was determined that it was possible to produce sausage by applying heat treatment at 60 °C at the end of fermentation for at least two days. However, the added starter culture was also destructed by heat treatment especially after two days of fermentation. As the fermentation time increased, the sensory quality properties of the heat treated sucuk improved and approached to traditionally fermented sucuk.

Keywords: fermented heat treated sausage, sucuk, fermentation interval, storage, heat treatment

Introduction

Since ancient times in history, fermented meat products have been kept at ambient temperatures by making minimal changes in product properties using hurdle technologies. Hurdle techniques such as fermentation, drying, antimicrobial effects of spices, lowering oxidation-reduction potential, bacterial competition, and acidity are used in fermented meats. Although fermented meat production was used for the preservation of meat in old times, today this process is preferred for maintaining the sensory properties formed during fermentation that are desired by consumers. The development of sensory properties in fermented sausages is related to the high number of reactions that occur during fermentation and drying. According to the philosophy of hurdle technology, the minimum required dose of each hurdle should be used for the maximum shelf life and product safety with minimum changes in product attributes while protecting the desired sensory properties (Lücke, 1994; Incze, 1998).

Sucuk is one of the most preferred fermented sausages in Turkey and also in Balkans, Middle East, Caucasia and Hither Asia. Sucuk is a dry, uncooked/unsmoked traditional fermented sausage mainly manufactured from beef. Traditional sucuk manufacture requires mastery and dexterity that limit the mass production and standardization (Stajic Perunovic Stanisic Zujovic and Zivkovic, 2013; Kargozari Moini Basti Emam-Djomeh Ghasemlou Martin Gandomi Carbonell-Barrachina and Szumny, 2014; Öztürk and Halkman, 2019).

Traditonal sucuk is a dry sausage, which mainly includes formulation with spontaneous microorganisms or starter culture addition, fermentation, drying and ripening stages (Fig. 1). The characteristics of sucuk are resulted from the complex biochemical, microbiological, physical and sensorial changes occurring in the meat batter during ripening under defined conditions of temperature, relative humidity and air velocity. The safety of sucuk is based on such factors as salt, additives (nitrite), lactic acid, low pH, and low water activity. However, the survival of foodborne pathogens such as *Escherichia coli* O157:H7 (Calicioglu Faith Buege and Luchansky, 2002; Cosansu and Ayhan, 2000), Salmonella Typhimurium (Erol and Hilderbrandt, 1992; Kara, 2007), *Listeria monocytogenes* (Kaya and Gökalp, 2004; Öztürk and Halkman 2019), *Helicobacter pylori* (Guner Kav Tekinsen Doğruer and Telli, 2011), *Yersinia enterocolitica* (Ceylan and Fung, 2000) and *Staphylococcus aureus* (Kaban and Kaya, 2006) during the fermentation and drying period is a major concern for the safety of sucuk. Heat treatment is considered as a new hurdle to eliminate these microbial risks in industrial bulk production of sucuk. On the other hand, the heat treatment application of sucuk is extending shelf life, shortening production time and decreasing production costs (Ercoşkun Tağı and Ertaş, 2010; Bilenler Karabulut and Candogan, 2017). In the manufacture of heat treated sucuk; sausage batters which are stuffed into casings are fermented for few days and then heat treatment is applied at various temperatures, relative humidity and air velocity to increase its internal temperature to 65–70 °C quickly (Ekici Ozturk Karaman Calıskan Tornuk Sagdic and Yetim, 2015).

The quality characteristics of fermented sausages are the result of mainly glycolysis, lipolysis and proteolysis that take place during production, catalysed by the meat and fat's autochthonous enzymes and by microorganisms added to sausage batter and/or contained in raw materials and/or contaminated during the production process. Glycolysis is the primary process of producing lactic acid and organic acids by microorganisms using the carbohydrates present in sausage batter as an energy and carbon source. As a result of this process, the pH and water holding capacity of the proteins decreases, the colour develops and the sausage starts to dry. A few days are sufficient under suitable conditions for the necessary glycolysis process. However, lipolysis, proteolysis and microbial oxidation reactions are secondary complex processes of microbial energy metabolism which take weeks to months to improve taste, odour and flavour formation of fermented sausage (Stahnke, 1994; Ozer Kılıc and Basyigit Kilic, 2016; Bosse Wirth Gibis Schmidt Weiss, 2021). In short fermented heat treated sucuk, case glycolysis can develop to decrease the pH with an optimized fermentation. However, lipolysis and proteolysis reactions either do not occur at all or can occur at a limited level in heat treated sucuks with lower taste, odour, flavour and colour formation (Ercoşkun et al., 2010; Bilenler et al., 2017). As a result of the variations of formulation, fermentation time and fermentation-heat treatment conditions, physicochemical properties have also been determined in a wide range in studies conducted with commercial sucuk samples (pH 4.5–6.9, moisture 26–47%, water activity 0.82–0.85, oil 23–41%, protein 15–20, ash 4–4.5%, salt 2.5–3.5% and residual nitrite 5–631 ppm) (Yaman Gökalp and Çon, 1998; Doğu Çon and Gökalp, 2002). There are also variations on the microbiology of sucuk; total viable count of 4–8 log CFU/g, Staphylococci/Micrococci (around 4 log CFU/g), *Enterobacteriaceae* (<10 to 4 log CFU/g), yeast and mould (<10 to 4 log CFU/g), lactic acid bacteria (2–6 log CFU/g), coliforms (< 1 to 3 log CFU/g) (Bozkurt and Erkmen, 2004).

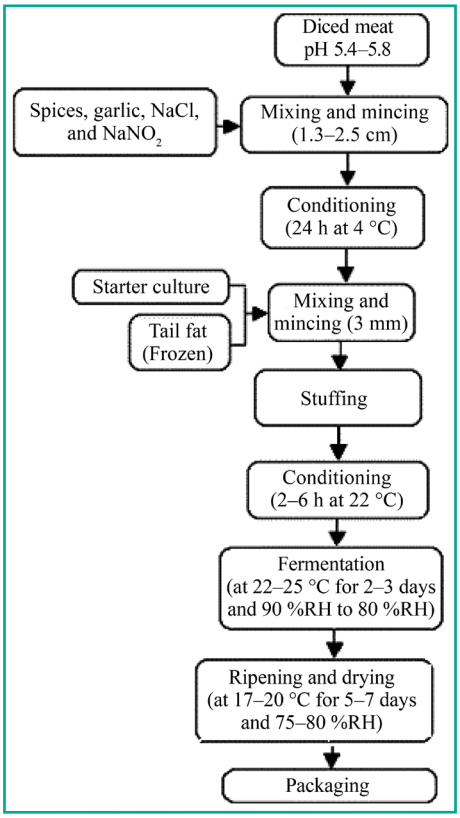

FIGURE 1: *The flow diagram of sucuk production.*

Studies for determining the effects of heat treatment of sucuk were mainly focused on the effect of the hygienic quality, fermentation time and fermentation-heat treatment conditions (Tayar, 1989; Filiz, 1996; Ducic Klisara Markov Blagojevic Vidakovic and Buncic, 2016; Bilenler and Karabulut 2019). Tayar (1989) used 45, 52, 60 and 62 °C; Filiz (1986) used 72 °C; Toptancı and Ercoşkun (2017) used 60, 65 and 70 °C and Ercoşkun et

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al., (2010) used 68 °C in heat treatment of sucuks. Turkish Food Codex (2018) is limiting the heat treatment temperature to at least 68 °C for heat treated red meat sucuk to avoid microbial risks based on the findings of the literature cited above. Heat treatment causes microbial destruction including starter culture, denaturation of proteins, accelerating oxidation, hardening the texture, spoiling the colour, changing flavour, aroma and taste which are decreasing the consumer demand. (Tayar, 1989; Ercoşkun et al., 2010; Toptancı and Ercoşkun, 2017; Bilenler and Karabulut 2019).

The aim of this study was to determine microbiological and physicochemical attributes of sucuks heat-treated at 60 °C for 10 minutes with increasing fermentation time up to 6 days and to make a comparison with the traditional sucuk during production and storage.

Materials and methods

Materials

The trial was replicated three times using different production lines from the same raw materials at the same time in a high capacity industrial scale meat processing plant. Spices, dry garlic, salt, sugar, nitrite, fibrous casing, beef and fat were supplied from the company. Beef fat was used because of its higher melting point compared to other animal fats. Beef and beef fat was used from the breast and thigh areas of two carcasses from 2 years old bulls. *Stapylococcus carnosus* and *Lactobacillus plantarum* were used as starter culture (BactofermTM T-D-66 Chr. Hansens Lab., Horsholm, Denmark).

Sucuk production

Sucuk mix was produced from beef, beef fat, clean dry garlic, spices, salt, sugar, nitrite, and starter culture in accordance with the following recipe; 90 kg beef (about 20% fat), 10 kg fat, 1.1 kg garlic, 0.9 kg red bell pepper, 1 kg cumin, 0.7 kg black pepper, 0.25 kg pimento, 2 kg salt, 0.4 kg sucrose, and 5 g $NaNO_2$. Salt, spices, garlic, nitrite and sucrose were added during the grounding of the beef using a 1.3 cm plate mincer. *S. carnosus* and *L. plantarum* was mixed during this step (10^7–10^8 cfu/kg). The meat batter was stored at 4 °C for 12 h. Frosted fat (–18 °C) was mixed gradually during grounding using a 3 mm plate. Approximately 100 g of sucuk mixture was filled into fibrous casing (Ø38 mm). Fermentation started at 20 °C, and 90% relative humidity. Relative humidity was reduced by 3% daily to reach 72% relative humidity on the 6th day. Sucuk groups were fermented for up to 6 days and a group of sucuk was treated with the heat every day in a controlled steam oven. Heat treatment is applied with a core temperature of 60 °C for 10 minutes. Several thermocouples are used for measuring the core temperature.

Sampling

From three batches, samples were collected on the 0, 1, 2, 3, 4, 5 and 6 days of fermentation prior and after heat treatment and additionally 9 days of fermented traditional sucuk. Polyethylene bags were used for vacuum packing of sucuk samples. Packed samples stored at 4oC and samples were taken on the 30th, 60th, and 90th days of storage. The pH, proximate composition (moisture, fat, protein ash and salt,), free fatty acidity, 2-thiobarbituric acid, residual nitrite, total haem pigments, nitrosomyoglobin and nitrosomyoglobin conversion ratio, instrumental colour analyses, and microbial enumerations were carried out in sucuk samples. A sensory panel was performed for fermented and heat treated sucuk samples and traditional sucuk samples after the production. All physicochemical, microbiological and sensorial analyses were duplicated.

Physicochemical analyses

A pH meter was used to measure pH value (Cole Parmer, Model 5996-50, USA). To determine moisture, drying of a homogenous mixture of the samples with sand and ethanol at 105 ± 2 °C was done until constant weight using an oven (Heraeus, Germany). The ash content (g/100 g) was analyzed by gravimetry after incineration at 550 °C for 24 hours to a white colour in a muffle oven (Heraeus, Germany). The micro Kjeldahl method was used in protein analysis (Büchi, Switzerland). A Soxhlet extractor was used with n-hexane (60 °C) for total fat analysis. Analyses regarding nitrosomyoglobin and total haem pigments contents were performed according to Zaika Zell Smith Palumbo and Kissinger, (1976). AOAC (1990) method was used for residual nitrite contents analysis. Alkaline titration method was used for FFA analysis. The method proposed by Tarladgis Watts Younathan and Dugan (1960) was used for thiobarbituric acid reactive substances (TBARS). All chemicals and solvents used were of analytical grade.

Determination of instrumental colour

Instrumental colour measurements were performed immediately after slicing (10 mm) the samples to prevent colour degradation because of light and oxygen. Hunter L*, a*, b* values were measured by a Minolta 508d colorimeter (Japan). The samples were sliced and wrapped with a single layer of stretch film. It was ensured that there was no gap between the sample surface and the film, and the readings were carried out on the surface of the wrapped samples by the colorimeter. Six readings were taken and averaged out for each replication.

Microbiological analyses

Total mesophilic aerobic bacteria (TMAB) enumerated with plate count agar (PCA, Merck) by spreading method with incubation temperature at 30 °C for up to 96 h. Double layer violet-red bile dextrose (VRBD) agar (Merck) was used in *Enterobacteriaceae* (TE) enumeration and typical colonies were counted after 24 hours of incubation at 37 °C. *Staphylococcus* and *Micrococcus* (SM) were enumerated with Baird Parker (BP) agar (Merck) by the spread-plate method supplemented with egg yolk and potassium telluride. Petri dishes were incubated at 37 °C for 72 hours. Lactic acid bacteria (LAB) were counted with double layer de Man Rogosa Sharpe (MRS) agar (Merck) and typical colonies were counted after 72 hours of incubation at 37 °C

Sensory evaluation

Heat-treated and traditional sucuk samples were used for sensory evaluation by ten experienced and trained panellists. The panel was repeated twice, and in each session, four randomized samples were served to the panel members. Evaluations were performed in individual booths under white fluorescent lighting at an ambient temperature of 20 °C. The panellists were provided unsalted bread and water at room temperature to clean the palate in between samples. Samples were cut into 5-mm thick slices after the casing was removed. Both raw and fried sausage slices on white plates marked with three random digits were evaluated. The sensory panel was duplicated.

Sucuk samples were assessed for taste, odour and aroma, flavour, spice ratio, internal redness, internal colour, consistency, cut surface appearance, chewiness, and overall acceptability on a 10-point hedonic scale (1 = dislike extremely – 10 = like extremely).

Statistical analyses

In the study, the data obtained before and after the heat treatment of sausages that were heat treated at different fermentation times and the data obtained during the storage period were evaluated using the repeated measured variance analysis technique. The analysis results for sucuk samples prior and after heat-treatment were compared with Student's t-test. There are 7 levels of fermentation time factor, two levels of processing factor with and without heat treatment, and 4 levels of storage factor. Tukey's multiple comparison test was carried out to clarify the significant differences among the means. All statistical analyses were carried out with Minitab (Minitab, State College, PA) software (ver. 13.0 for Windows).

The mean pH values of sucuk samples during production and storage are shown in Figure 2. Fermentation time and heat processing significantly affected pH values of sucuk during processing ($P < 0.05$). The initial pH value of sucuk batter was 5.88±0.05 and dropped to 4.81±0.01 on the 5th day of fermentation. Traditional sucuk pH value dropped to 5.0±0.13 in 9 days of fermentation. Similar pH decreases in the fermentation of traditional sucuk have been reported by several authors (Tayar, 1989; Filiz, 1996;

TABLE 1: The moisture, salt, ash, fat and protein contents of sucuk samples (%).

		Fermentation Time (Days)							Trad.
	Time	0	1	2	3	4	5	6	Sucuk
Moisture (%)	Prior heat treatment	57.98 ±0.10^{Aa}	54.65 ±0.09^{Ba}	51.71 ±0.03^{Ca}	49.75 ±0.11^{Da}	47.74 ±0.13^{Ea}	45.30 ±0.16^{Fa}	43.62 ±0.13^{Ga}	35.29 ±0.19^{H}
	After heat treatment	55.36 ±0.25^{Ab}	52.56 ±0.23^{Bb}	50.43 ±0.13^{Cb}	48.57 ±0.13^{Db}	47.42 ±0.94^{Eb}	44.47 ±0.15^{Fb}	43.09 ±0.12^{Gb}	
Salt (%)	Prior heat treatment	2.407 ±0.021^{Aa}	2.547 ±0.021^{Ba}	2.667 ±0.021^{Ca}	2.747 ±0.021^{Da}	2.823 ±0.025^{Ea}	2.923 ±0.031^{Fa}	2.990 ±0.036^{Ga}	3.33 ±0.03^{H}
	After heat treatment	2.520 ±0.040 ^{Ab}	2.637 ±0.031 ^{Bb}	2.727 ±0.031 ^{Cb}	2.800 ±0.040 ^{Db}	2.867 ±0.051 ^{Eb}	3.050 ±0.132 ^{Fb}	3.043 ±0.05 ^{Gb}	
Ash (%)	Prior heat treatment	3.330 ±0.010 ^{Aa}	3.487 ±0.015 ^{Ba}	3.703 ±0.015 ^{Ca}	3.767 ±0.006 ^{Da}	3.893 ±0.021 ^{Ea}	4.033 ±0.015 ^{Fa}	4.150 ±0.010 ^{Ga}	4.57 ±0.02 ^{H}
	After heat treatment	3.483 ±0.059 ^{Ab}	3.670 ±0.052 ^{Bb}	3.753 ±0.059 ^{Cb}	3.857 ±0.064 ^{Db}	3.960 ±0.061 ^{Eb}	4.110 ±0.044 ^{Fb}	4.190 ±0.044 ^{Gb}	
Fat (%)	Prior heat treatment	25,54 ±0.05^{Aa}	26,95 ±0.02^{Ba}	28,22 ±0.02^{Ca}	29,03 ±0.01^{Da}	29,90 ±0.02^{Ea}	30,80 ±0.01^{Fa}	31,65 ±0.17^{Ga}	35,21 ±0.02^{H}
	After heat treatment	26,58 ±0.55^{Ab}	27,85 ±0.02^{Bb}	28,76 ±0.01^{Cb}	29,54 ±0.02^{Db}	30,31 ±0.05^{Eb}	31,28 ±0.02^{Fb}	31.89 ±0.05^{Gb}	
Protein (%)	Prior heat treatment	12.65 ±0.05^{Aa}	13.47 ±0.17^{Ba}	13.94 ±0.22^{Ca}	14.46 ±0.20^{Da}	14.81 ±0.28^{Ea}	15.48 ±0.14^{Fa}	15.74 ±0.15^{Ga}	17.38 ±0.25^{G}
	After heat treatment	13.35 ±0.31^{Ab}	13.97 ±0.31^{Bb}	14.24 ±0.09^{Cb}	14.66 ±0.20^{CDb}	14.96 ±0.15^{Db}	15.60 ±0.10^{Eb}	15.89 ±0.05^{Fb}	

$^{a-b}$ Means in the same column with different lowercase superscripts are significantly different (P<0.05).
$^{A-H}$ Means in the same row with different capital superscripts are significantly different (P<0.05).
Values are given as mean ±S.D. from duplicate determinations.
n:3

Results

Table 1 shows the proximate composition of sucuk samples during production. While the moisture content of traditional and heat treated sausages decreased during fermentation, their protein, fat, ash and salt contents increased. As the pH during fermentation approaches the isoelectric point of meat proteins, the water holding capacity of the proteins decreases. In this process, the bounded water to protein molecules turns into free water and drying takes place. The moisture content of the sausage decreases with the drying which occur during the fermentation and the amounts of protein, fat, ash and salt that make up the dry matter increases.

Moisture content decreased significantly after the heat process in all fermentation intervals ($P < 0.05$). It was also observed that the difference between moisture contents before and after heat treatment decreased with the increased fermentation time ($P < 0.05$). The decrease in moisture content could be the result of the decrement in water holding capacity of proteins that are denaturated throughout heat treatment which was determined by other authors (Tayar, 1989; Filiz, 1996). The effect of 3 months storage time on the moisture, salt, ash, protein and fat contents of heat treated and traditional sucuk was not significant ($P < 0.05$) since moisture losses were prevented due to vacuum packing.

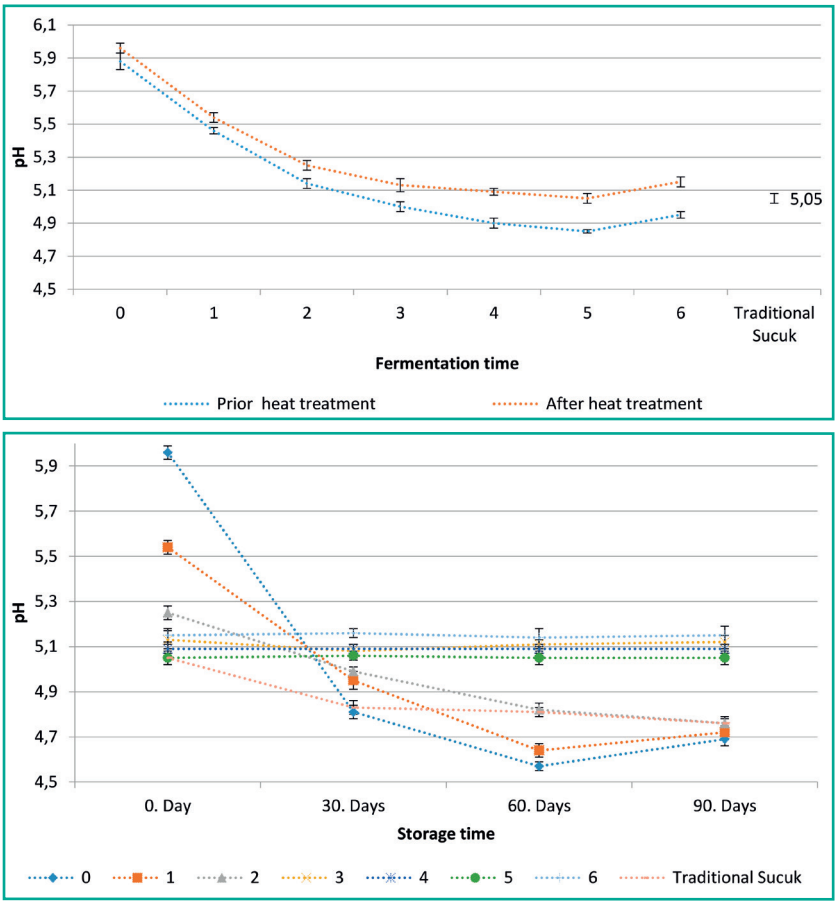

FIGURE 2: *The mean pH values of sucuks samples during production (top) and storage (down) (n:3).*

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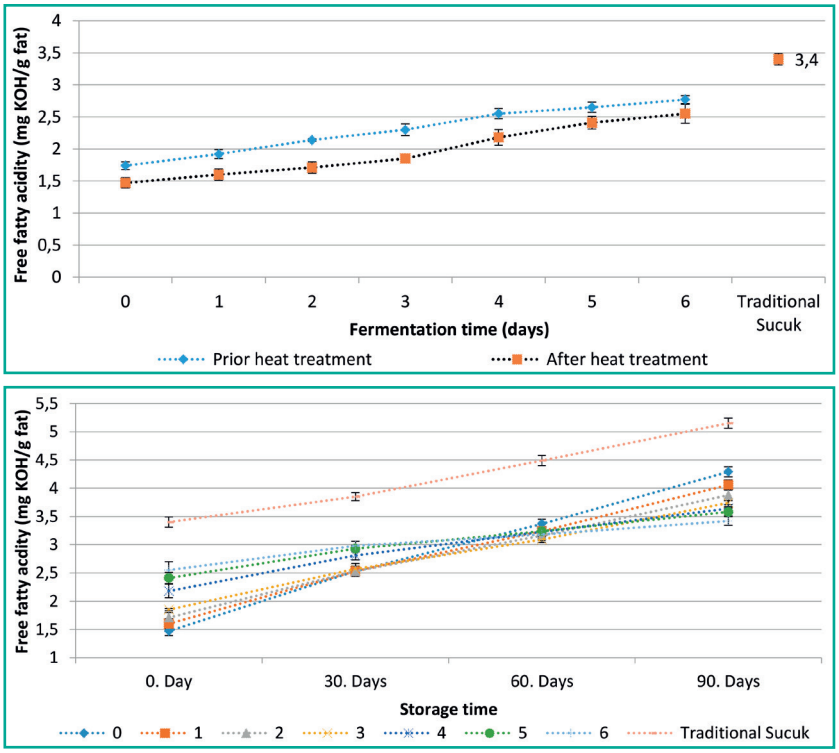

FIGURE 3: *Mean FFA values of sucuk samples during production (top) and storage (down) (n:3).*

Dalmış and Soyer, 2008; Coskuner, Ertas and Soyer, 2010). The rapid pH drop during fermentation took place in the first two days and slowed the pace of decline in the next few days. The pH decrease is a consequence of the activity of added or naturally occurring lactic acid bacteria to produce organic acids mainly lactic acid from simple carbohydrates present in meat tissues and sucrose added to sucuk batter. The decrement in the number of fermentable carbohydrates also decreased the speed of acidification. The decline in the pH value during the fermentation period is very important due to the formation of several desired quality and safety parameters in sucuk such, as the inhibition of undesired bacteria, flavour, colour, texture formation, etc.

On the other hand, heat treatment significantly increased the pH values and as the fermentation time increased, the difference between pH values increased. ($P < 0.05$). Toptancı and Ercoşkun (2017) applied heat to sucuk at 60 (for 15 minutes), 65 (for 10 minutes) and 70 °C (as reached) after 3 days of fermentation and concluded that the pH increment during heat treatment may be a result of thermal protein denaturation. During fermentation, the buffering capacity of the proteins may have increased as the amount of dry matter and salt increases and the pH value decreases. Other authors also reported that as the fermentation time increased in heat treated sucuk, the difference between pH values before and after heat treatment increased (Tayar, 1989; Filiz, 1996; Ercoşkun et al., 2010).

The pH values of heat treated sucuk samples which were fermented for 0, 1 and 2 days were decreased ($P < 0.05$) while there was no change in pH values of heat treated sausage samples fermented for 3, 4, 5 and 6 days during refrigerated storage. The pH value of traditional sucuk also showed a slight decrease.

Ercoşkun et al. (2010) reported that the bacterial destruction effect of the heat treatment application in sucuk increases as the pH value decreases. In this study, it is evaluated that there is no change in the pH value during the storage since there is no bacteria left to reduce the pH value in sucuk that have been heat treated after the 3rd day of fermentation.

Mean FFA values of sucuk samples during production and storage are shown in Figure 3. The FFA values of samples prior heat treatment increased during processing. The initial FFA was 1.74 and it was measured as 2.77 mg KOH/g fat on day 6. Traditional sucuk's FFA value was 3.40±0.09 mg KOH/g fat. These results were in good agreement with other studies on fermented sausages (Stahnke, 1994). FFA are formed as a result of lipolysis, one of the main reactions that take place in the production of fermented meat products. Lipolysis reactions are catalysed by bacterial lipases and endogenous muscle lipases, respectively. Fatty acids can also be liberated by auto hydrolysis and can affect free fatty acid much less than enzymatic hydrolysis. It is stated that FFA increases during maturation and storage in fermented meat products as a result of lipolysis reactions and reaches from 1–2% to 4–5% within 1 month. However, free fatty acids formed by lipolysis can be broken down by microbial metabolisms and auto-oxidation reactions (Demeyer Hoo-

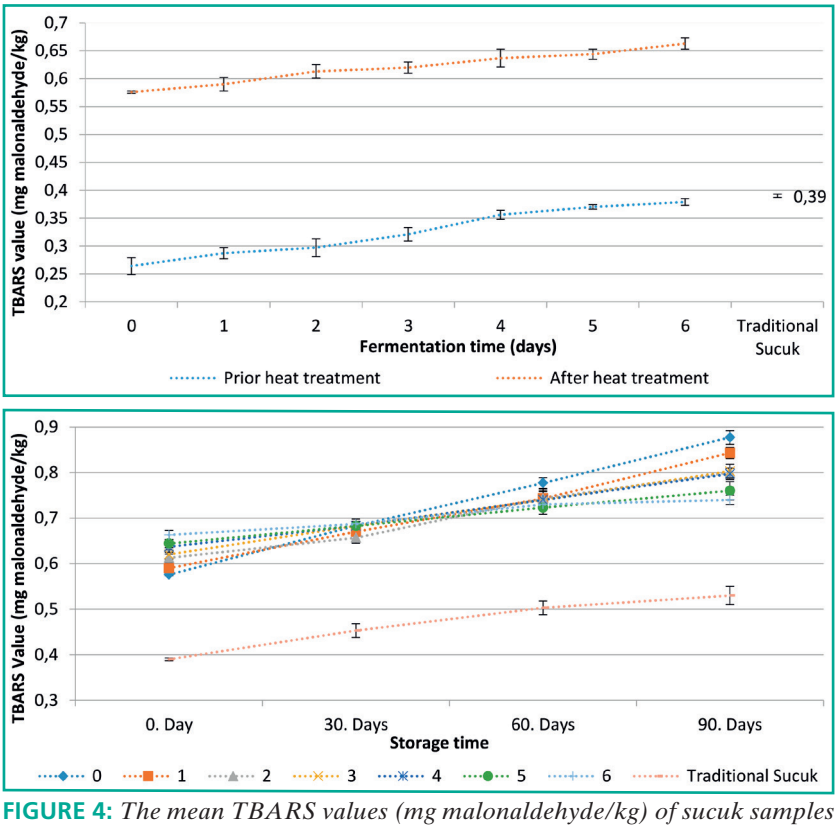

FIGURE 4: *The mean TBARS values (mg malonaldehyde/kg) of sucuk samples during processing (top) and storage (down) (n:3).*

zee and Mesdom, 1974; Toldra, 1998). The findings of this study are confirming lipase activities increase with decreasing pH value in dry cured meat products.

FFA values of sucuk samples significantly decreased during the heat treatment (P<0.05). The decrement in FFA value during heat treatment may be caused by the oxidation of labile unsaturated free fatty acids. FFA decrements during heat treatment of sucuk were reported by Coskuner et al. (2010) at 73 °C (for 10 min.) heat treatment temperature and Ercoşkun et al. at 68 °C (as reached) heat treatment temperature. Toptancı and Ercoşkun (2017) heat treated sucuks at 60 (for 15 minutes), 65 (for 10 minutes) and 70 °C (as reached) after 3 days of fermentation and reported that as the heat treatment temperature increased the FFA value decreased.

The FFA values of all sucuk samples increased during the refrigerated storage (P<0.05); however, it was observed that the traditional sucuk showed the highest FFA values during storage. Bacterial lipolysis is a secondary metabolism and is less affected by factors such as ambient temperature, water activity and pH. While most enzymes are inhibited at water activities below 0.6 aw, bacterial lipase enzymes can maintain their activity even at 0.2 aw. Since microbial lipases and muscle lipases are denatured by heat treatment, free fatty acids formed in heat treated sausages were formed by auto hydrolysis. However, FFA formation in traditional sucuk resulted from the activity of microbial and endogenous lipases and auto hydrolysis.

The mean TBARS values of sucuk samples during processing and storage are shown in Figure 4. Sucuk samples prior and after heat treatment showed a significant increment in TBARS values during the fermentation period (P<0.05). A significant increase in TBARS values of sucuks was observed due to the heat treatment (P<0.05), showing that oxidative reactions were accelerated along the heat process. Ercoskun et al. (2010) reported TBARS values increment in heat treatment of sucuks at 68 °C. TBA values were reported as 0.62, 0.63 and 0.65 mg malonaldehyde / kg product in sausages that were heat treated at 60 (for 15 minutes), 65 (for 10 minutes) and 70 °C (as reached) after being fermented for 3 days (Toptancı and Ercoşkun, 2017). The TBARS values of all sucuks significantly increased during storage (P<0.05).

The TBARS values of sucuks heated on the 0th day showed the fastest increase and sucuks heated on the 6th day showed the slowest increase among heat treated sucuk samples. The TBARS values of traditional sucuks were the smallest in all samples during the refrigerated storage. Erkmen and Bozkurt (2004) reported that TBA values of retailed sucuks ranged from 0.51 to 2.11 mg malonaldehyde/kg while our findings ranged from 0.4–0.9 mg malonaldehyde/kg.

Figure 5 shows the mean residual nitrite contents (ppm) of sucuk samples during processing and storage. In this study, 50 ppm nitrite was added to sausage dough. Residual nitrite contents of samples before and after heat treatment decreased significantly along the fermentation time (P<0.05), heat process significantly decreased the residual nitrite levels (P<0.05) and residual nitrite levels of all sucuk samples significantly decreased during the storage (P<0.05). The highest residual nitrite content was observed in the 0th day and residual nitrite contents decreased with increased fermentation time in both before heat treatment and after heat treatment. The residual nitrite levels were also decreased during refrigerated storage significantly (P<0.05). Nitrite used in cured meat products interacts with various constituents in the complex systems of meat and main purposes of using nitrite are colour formation-stabilization, flavour formation, antioxidant and inhibitor of pathogenic microflora, in particular *Clostridium botulinum*. Turkish Food Codex allows the use of 150 ppm nitrite, but it has been reported that 50 ppm nitrite is sufficient for the colour in heat treated sucuk. (Yürür Ertaş and Ercoşkun, 2012). The residual nitrite is considerably lower than the added amount since it interacts with mainly myoglobin in addition to various constituents of the meat during the manufacturing process. Some starter cultures might have influenced the reduction of residual nitrite during fermentation at various degrees. Lactic acid bacteria have been reported to be responsible for nitrite depletion by lowering the pH by producing lactic acid. Some lactic acid bacteria have been also reported to have nitrite reductase, which can reduce nitrite concentrations under anaerobic conditions (Dodds and Collins-Thompson, 1984; Oh Oh and Kim, 2004; Yan Xue Tan Zhang and Chang, 2008). Residual nitrite content remains

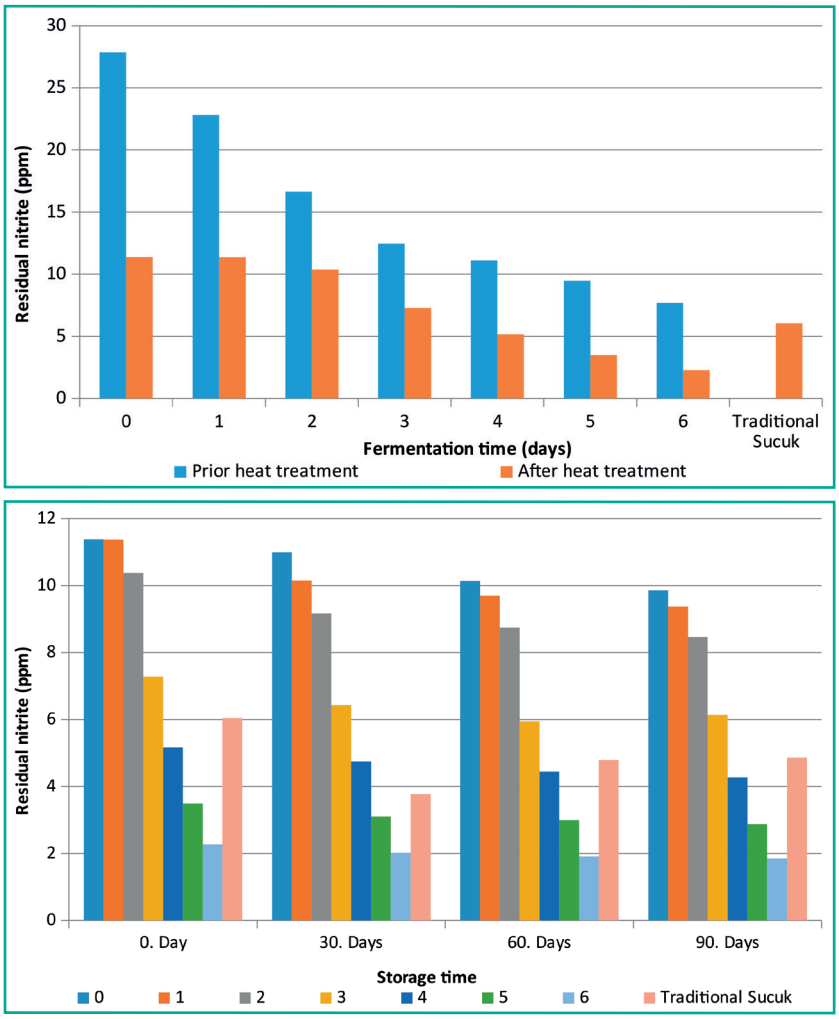

FIGURE 5: *The mean residual nitrite contents (ppm) of sucuk samples during processing (top) and storage (down) (n:3).*

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a significant problem because it leads to the formation of toxic compounds. The residual nitrite levels in traditional sucuks have been reported in the range of 4.30 and 62.59 mg/kg (Gürbüz and Çelikel Güngör 2020).

Approximately 99% myoglobin and less than 1% hemoglobin constitute the colour of the meat or meat product. Reactions between myoglobin and added nitrite play a key role in the formation and stability of the characteristic red colour in fermented meat products. At the beginning of fermentation, myoglobin starts to react with nitrite added to the sausage paste. Myoglobin and nitrite concentrations are essential for the reaction, but decreasing pH and redox potential during fermentation directly determines the course of reactions. During the fermentation process, nitric oxide (NO) is generated from the reduction of nitrite, and then NO interacts with the myoglobin to form nitrosomyoglobin (NO-Mb), which produces the typical colour of cured meat. The pH and redox potential that decreases with fermentation accelerates the formation of nitrosomyoglobin and after a point the decrease in pH and redox potential stops. After this stage, the amount of nitrosomyoglobin slightly decreases with microbial and enzymatic reactions. Many researchers have reported that the reaction between nitrite and myoglobin accelerated with the application of heat treatment in cured meat products (Zaika et al. 1976; Trout 1989; Astiasaran Redin Cid Iriarte and Bello, 1993; Üren and Babayiğit 1996; Hunt Sorheim and Slinde, 1999; Zhu and Brewer 2002; Yürür et al 2012). Table 2 shows nitrosomyoglobin, total haem pigments contents, nitrosomyoglobin conversion ratios and L*, a* and b* values of the sucuk samples. The amount of nitrosomyolobin in the sausages before the heat treatment increased rapidly in the first days of fermentation and then the increase slowly continued ($P<0.05$). The amount of nitrosomyolobin in sucuk after heat treatment increased in the first two days of fermentation ($P<0.05$) and stabilized in the following days ($P<0.05$), but traditional sucuk showed the highest nitrosomyoglobin contents. The amount of total haem pigment in sausages prior to the heat treatment was determined between 208.65–214.43 ppm and 187.00–185.58 ppm after heat treatment (Table 2). In the traditional sausage, this value was 215.33 ppm. Heat treatment reduced the total amount of haem pigment significantly ($P<0.05$). The conversion rate of nitrosomyoglobin increased in the sausages prior the heat treatment for the first two days and then it remained constant. The same value remained almost constant in sausages after heat treatment. The reaction of approximately 60% of myoglobin with nitrite is important for acceptable colour formation (Lücke, 1994; Öztan, 2005).

L* value decreased in sausages prior and after heat treatment after the second day of fermentation and heat treatment application decreased L* value ($P<0.05$) (Table 2). L* value of sucuk samples decreased in cold storage with vacuum packaging. The decrease of L* values was also monitored by other studies during the fermentation and storage in traditional sucuk (Kayaardı and Gök, 2004; Bozkurt and Bayram, 2006). The decrease in L* value represents the formation of dark colour in the sucuk due to drying. Traditional sucuk had lower L* value compared to other samples. The lower L* value during the ripening is also attributed to the moisture loss, in traditionally fermented sucuks (Kayaardı and Gök 2004).

The value a* represents the degree of redness formed by mainly concentration of nitrosomyoglobin (Yürür et al. 2012). Since the myoglobin-nitrite reaction affecting the a* value occurs at low pH, it occurred rapidly on the 1st and 2nd days of fermentation, especially when the pH decreased rapidly, and the rate of increase in nitrosomyoglobin and a* value slowed in the following days (Table 2). Heat treatment significantly decreased ($P<0.05$) the a* values on the first 3 days but

TABLE 2: The nitrosomyoglobin (ppm), total haem pigments (ppm) contents, nitrosomyoglobin conversion ratios (%) and L*, a* and b* values of the sucuk samples.

		Fermentation Time of Heat Treated Sucuks (Days)							
	Time	0	1	2	3	4	5	6	Trad. Sucuk
NMB	Prior heat treatment	75.49 ±1.56 ^{Fa}	143.64 ±0.80 ^{Ea}	160.18 ±1.97 ^{Da}	165.54 ±1.84 ^{Ca}	169.32 ±2.67 ^{Ba}	170.95 ±2.20 ^{Ba}	177.33 ±1.82 ^{Aa}	
	After heat treatment	136.36 ±0.81 ^{Db}	141.76 ±1.48 ^{Ca}	150.22 ±1.52 ^{Bb}	149.06 ±2.77 ^{Bb}	150.65 ±0.67 ^{Bb}	151.62 ±1.55 ^{Bb}	152.02 ±4.70 ^{Bb}	183.32 ±1.75 ^{A}
THP	Prior heat treatment	208.65 ±0.71 ^{Ba}	209.55 ±0.71 ^{Ba}	210.79 ±0.91 ^{ABa}	212.39 ±3.16 ^{ABa}	214.77 ±1.09 ^{Aa}	214.70 ±1.05 ^{ABa}	214.43 ±1.19 ^{Aa}	
	After heat treatment	187.00 ±0.90 ^{Bb}	187.68 ±2.36 ^{Bb}	188.97 ±3.14 ^{Bb}	185.81 ±0.61 ^{Bb}	185.64 ±4.12 ^{Bb}	186.83 ±3.12 ^{Bb}	185.58 ±2.99 ^{Bb}	215.33 ±3.07 ^{A}
NCR	Prior heat treatment	36.18 ±0.77 ^{Ea}	68.54 ±0.60 ^{Da}	75.90 ±0.68 ^{Ca}	77.95 ±0.30 ^{BCa}	78.87 ±1.11 ^{BCa}	79.62 ±0.87 ^{ABa}	82.72 ±1.32 ^{Aa}	
	After heat treatment	72.88 ±0.46 ^{Cb}	75.56 ±0.97 ^{Cb}	79.51 ±2.08 ^{Bb}	80.26 ±1.79 ^{Ba}	81.22 ±2.10 ^{ABa}	80.97 ±2.24 ^{Ba}	81.96 ±3.65 ^{ABa}	85.16 ±2.03 ^{A}
L*	Prior heat treatment	48.45 ±0.13 ^{Aab}	48.54 ±0.14 ^{Aab}	48.36 ±1.37 ^{Aa}	47.06 ±0.22 ^{Ba}	46.18 ±0.40 ^{Ba}	46.01 ±0.39 ^{Ba}	45.95 ±0.67 ^{Ba}	
	After heat treatment	50.23 ±0.30 ^{Aa}	49.92 ±0.38 ^{ABb}	50.28 ±0.25 ^{Ab}	50.09 ±0.23 ^{ABb}	49.49 ±0.44 ^{Bb}	47.91 ±0.21 Cb	47.04 ±0.42 ^{Da}	45.97 ±0.42 ^{Ea}
	30 days of storage	47.69 ±0.80 ^{Abc}	47.39 ±0.41 ^{Aab}	47.64 ±0.76 ^{Ab}	47.33 ±0.74 ^{Aa}	46.98 ±0.81 ^{Aa}	45.48 ±0.35 ^{Ba}	44.66 ±0.33 ^{Bb}	43.64 ±0.36 ^{Cb}
	60 days of storage	46.24 ±1.25 ^{Ac}	45.94 ±0.81 ^{Ac}	46.28 ±1.20 ^{Ab}	46.11 ±1.16 ^{Aa}	45.56 ±1.24 ^{ABa}	44.10 ±0.78 ^{Bc}	43.19 ±0.58 ^{Cc}	42.36 ±0.74 ^{Cbc}
	90 days of storage	45.80 ±1.75 ^{Ac}	45.48 ±1.25 ^{ABc}	45.83 ±1.65 ^{Ac}	45.64 ±1.60 ^{Aa}	45.09 ±1.68 ^{ABa}	43.70 ±1.16 ^{ABc}	42.86 ±1.11 ^{BCc}	42.12 ±1.26 ^{Cc}
a*	Prior heat treatment	16.81 ±0.18 ^{Aa}	17.30 ±0.10 ^{Ba}	17.77 ±0.05 ^{Ca}	18.35 ±0.13 ^{Da}	18.39 ±0.16 ^{Da}	18.26 ±0.23 ^{Da}	18.09 ±0.16 ^{Da}	
	After heat treatment	15.89 ±0.31 ^{Ab}	15.75 ±0.30 ^{ABb}	16.28 ±0.37 ^{Bb}	17.20 ±0.27 ^{Cb}	18.65 ±0.41 ^{Da}	18.51 ±0.32 ^{Da}	18.28 ±0.22 ^{Da}	15.44 ±0.34 ^{Aa}
	30 days of storage	14.59 ±0.33 ^{Ac}	14.64 ±0.27 ^{Ac}	15.30 ±0.35 ^{Ac}	16.34 ±0.26 ^{Ac}	17.89 ±0.39 ^{Aa}	17.98 ±0.31 ^{Aa}	12.61 ±9.39 ^{Aa}	14.68 ±0.35 ^{Aa}
	60 days of storage	13.68 ±0.34 ^{Ad}	14.33 ±0.25 ^{Ac}	14.32 ±0.86 ^{Ad}	15.54 ±0.68 ^{Bd}	16.73 ±0.57 ^{Cb}	17.04 ±0.66 ^{Cb}	17.21 ±0.57 ^{Ca}	13.86 ±0.72 ^{Cb}
	90 days of storage	13.44 ±0.19 ^{Ad}	13.35d ±0.33 ^{A}	13.95 ±0.43 ^{Ad}	14.93 ±0.20 ^{Bd}	16.32 ±0.53 ^{Cb}	16.39 ±0.46 ^{Cb}	16.34 ±0.36 ^{Ca}	13.40 ±0.38 ^{Ab}
b*	Prior heat treatment	18.34 ±0.08 ^{Aa}	18.26 ±0.15 ^{Aa}	18.03 ±0.15 ^{Aa}	17.88 ±0.13 ^{ABa}	17.69 ±0.29 ^{Ba}	17.36 ±0.24 ^{Ca}	17.24 ±0.15 ^{Ca}	
	After heat treatment	20.06 ±0.22 ^{Ab}	19.98 ±0.72 ^{Aa}	19.42 ±0.36 ^{ABb}	19.27 ±0.40 ^{Bb}	19.47 ±0.23 ^{ABb}	18.80 ±0.36 ^{BCc}	18.32 ±0.23 ^{Cc}	12.10 ±0.19 ^{Da}
	30 days of storage	18.51 ±0.44 ^{Aa}	18.89 ±1.05 ^{Ab}	18.34 ±0.56 ^{Aa}	18.60 ±0.22 ^{Aab}	18.76 ±0.66 ^{Ab}	18.54 ±0.25 ^{Ac}	17.97 ±0.47 ^{Ac}	11.45 ±0.37 ^{Bb}
	60 days of storage	17.63 ±0.44 ^{Ac}	17.69 ±0.59 ^{Ab}	17.81 ±0.44 ^{Aa}	17.79 ±0.75 ^{Ac}	18.61 ±0.33 ^{Ab}	18.11 ±0.70 ^{Ac}	18.20 ±0.37 ^{Ac}	10.84 ±0.34 ^{Bc}
	90 days of storage	16.11 ±0.42 ^{ABd}	16.88 ±1.04 ^{ABc}	16.72 ±0.40 ^{Ac}	17.14 ±0.08 ^{Ac}	17.64 ±0.66 ^{Aa}	17.62 ±0.14 ^{Aa}	17.60 ±0.38 ^{Ab}	10.63 ±0.34 ^{Cc}

$^{a-e}$ Means in the same column with different lowercase superscripts are significantly different ($P<0.05$).
$^{A-H}$ Means in the same row with different capital superscripts are significantly different ($P<0.05$).
Values are given as mean ±S.D. from duplicate determinations.
NMB: Nitrosomyoglobin; THP: Total heme pigments; NCR: Nitrosomyoglobin conversion ratio. n:3

significantly increased (P<0.05) the a* values after the 3rd day that may be related to the pH and isoelectric point of myoglobin. The a* values of all sucuks decreased significantly during the storage time (P<0.05). Similar results for traditional sucuk were also reported by other researchers (Kayaardı and Gök, 2004; Bozkurt and Bayram, 2006).

The b* values significantly decreased (P<0.05) in sucuks prior to heating during the fermentation (Table 2). The observed changes in b* might be due to the decrease of oxygen by microorganisms during the fermentation and the decrease in oxymyoglobin that may be contributes to the colour change. Heat process increased b* values of all sucuk samples (P<0.05). The b* values of all samples decreased during storage (P<0.05).

Figure 6 shows the total mesophilic aerobic bacteria counts of sucuk samples during product and storage. The total mesophilic aerobic bacterial (TMAB) count was initially 7.53 ± 0.10 log CFU/g and increased to 8.78 ± 0.11 log CFU/g (P>0.05) during fermentation. Then, it remained constant during 1–5 days of fermentation and then decreased to 7.25 ± 1.65 log CFU/g on day 6, and 8.37 ± 0.12 log CFU/g on day 9 (P<0.05). Heat treatment significantly decreased TMAB count in all fermented and heat treated samples (P<0.05). Ercoşkun et al. (2010) reported that the initial TMAB count of sucuk as 7.91 ± 0.03 log cfu/g, this number was decreased to 5.23 ± 0.28 log cfu/g with nine days of fermentation. Nazlı (1998) reported that the initial TMAB count of 7.40 and 5.7 and 6.48 log cfu/g for the 6th and 9th days of fermentation, respectively. Contradictorily, higher TMAB counts, which were initially 7.54 ± 0.22 log cfu/g increased to 8.60 ± 0.16 log cfu/g after 8 days of ripening in sucuk, were reported by Bozkurt and Erkmen (2002).

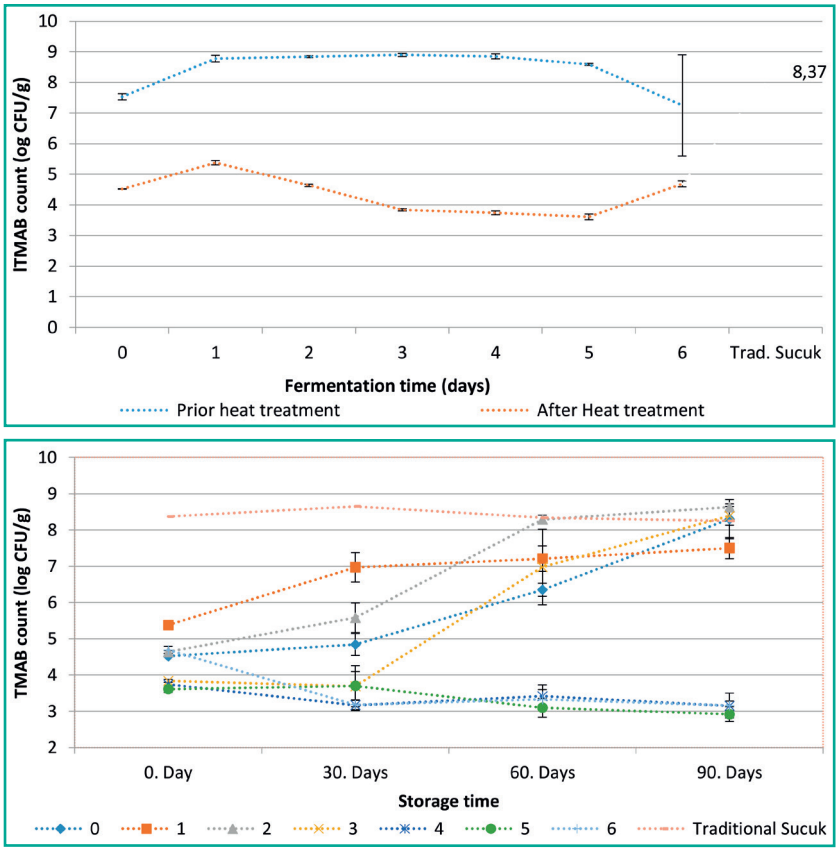

FIGURE 6: *Total mesophilic aerobic bacteria counts of sucuk samples (log cfu/g) during production (top) and storage (down) (n:3).*

The TMAB counts of 4 and 6 day fermented and heat treated sucuks remained constant during the storage (P<0.05). However, the TMAB counts of 0–3 day fermented and heat treated samples increased during the storage (P<0.05). Bilenler et al. (2017) reported that the TMAB counts of 24-hour fermented beef sucuk were found as 5.12–6.28 log cfu/g and after heat treatment at 70 °C, the TMAB count decreased to 2.60–3.85 log cfu/g. Dalmış and Soyer (2008) reported that the initial TMAB counts of beef sucuk as 5.2–6 log cfu/g, this count increased to 8 log cfu/g in 2–4 days of fermentation and after heat treatment at 68 °C decreased to 7 log cfu/g.

The TMAB counts of heat treated sucuk samples after different fermentation times showed significant differences during the refrigerated storage. The TMAB count of traditional sucuk samples was 8.37±0.16 log cfu/g at the beginning of storage, and 8.25±0.12 log cfu/g at the end of 3-month storage. The TMAB counts of 0, 1, 2 and 3 days fermented and heat treated sucuk samples showed a significant increase during refrigerated storage (P<0.05) while the TMAB counts of 4, 5 and 6 days fermented and heat treated sucuk samples showed a significant decrease (P<0.05). These results showed the thermal stress to which the mesophilic and aerophilic bacteria are exposed depending on the variables such as different pH, salt content and moisture content of the sausages when heat treatment is applied. As the fermentation time increased up to 3 days, the mesophilic and aerophilic bacterial contents of the sucuk samples survived against the decreased pH value, the decreased moisture and the increased salt content; however, the rate of increase of their numbers increased due to thermal stress after the first month. Mesophilic and aerophilic bacteria of sucuk samples that were fermented 4, 5 and 6 days and heat treated showed the effects of thermal stress until the end of storage. The TMAB counts of the traditional sucuk samples remained almost constant, as expected.

Figure 7 shows the lactic acid bacteria counts of sucuk samples during production and storage. Lactic acid bacteria (LAB) counts of sucuk samples before heat treatment increased from the initial number of 6.89 to 9.18 log CFU/g (P<0.05) and then decreased to 7.45 log CFU/g (P<0.05) on the 6th day of fermentation. The final count was 7.81 log CFU/g in the traditional sucuk. Similar results were also reported for LAB counts during fermentation by other researchers (Tayar, 1989; Filiz, 1996). Heat treatment significantly decreased LAB counts in all fermented and heat treated sucuk samples (P<0.05). No significant change in LAB counts was observed in traditional sucuk samples during storage (P>0.05). LAB counts of 4 and 5 days fermented and heat treated sucuk samples significantly decreased below 1 log cfu/g in the first month of storage(P<0.05). LAB counts of 6 days fermented and heat treated sucuk samples were under 2 log cfu/g. LAB counts of 3 days fermented and heat treated sucuk samples decreased until the first month and then increased until the end of storage (P<0.05). LAB counts of 0, 1 and 2 days fermented and heat treated sucuk samples increased during storage (P<0.05).

Figure 8 shows the mean SM counts of sucuk samples (log cfu/g) during production and storage. SM counts sho-

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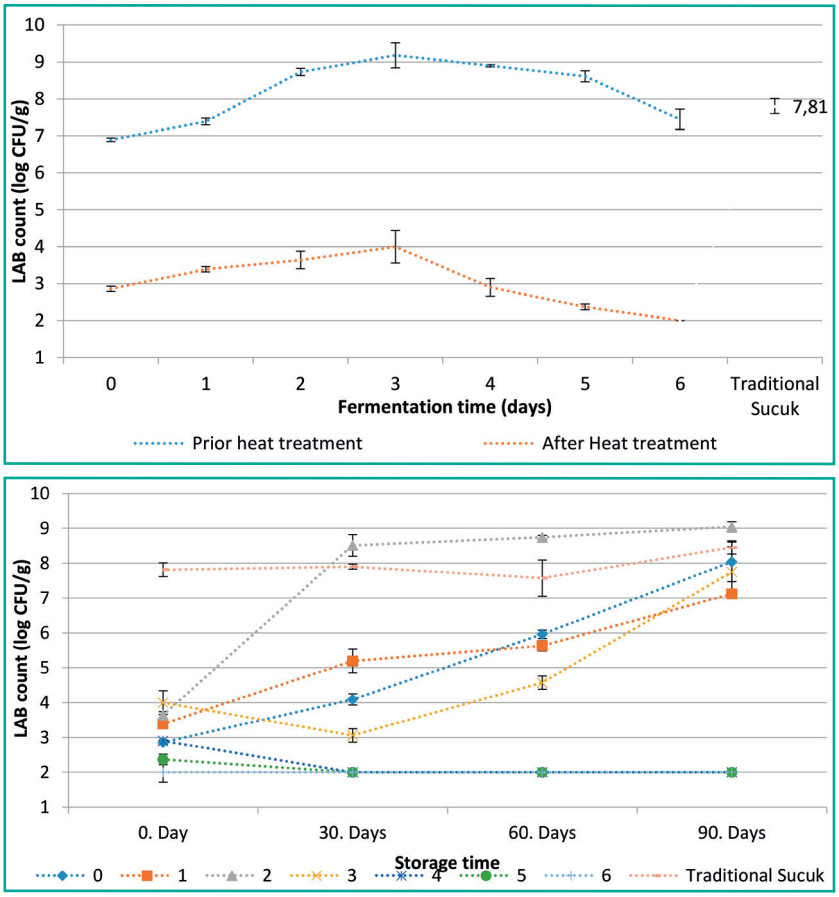

FIGURE 7: *Lactic acid bacteria counts of sucuk samples (log cfu/g) during production (top) and storage (down) (n:3).*

wed a decrease from an initial value of 6.83 ± 0.01 to 4.30 ± 0.14 log CFU/g on the 5th day (P<0.05), then increased to 5.81 ± 0.13 log CFU/g on the 6th day, and finally 6.05 ± 0.01 log CFU/g in the traditional sucuk. Baird Parker medium, one of the most common media used for SM count, was used in this study. Baird-Parker agar inhibits bacteria other than SM due to potassium tellurite and lithium chloride contained in its formula. However, some *Bacillus* and *Corynebacterium* strains can grow on Baird parker agar medium. Of course, the counts obtained on Baird Parker agar, which is a selective medium, will be lower than the counts obtained in general media. It is expected that the temperature, air circulation rate and relative humidity in all parts of the fermentation chamber will be the same. However, this is not always the case, especially in large-volume industrial chambers. It is thought that the fluctuation in SM bacteria counts, especially on the 4th and 5th day, may be the sampling error caused by the heterogeneous climate of the fermentation chamber. Heat treatment significantly decreased SM counts during the fermentation (P<0.05). The SM counts of sucuk significantly changed during storage; 4 and 5 days fermented and heat treated sucuk samples showed a dramatic decrement on first month on storage and after first month the SM counts of them decreased below countable level. The SM counts of three days fermented and heat treated sucuk samples increased significantly (P<0.05) until 2 month of storage and then decreased to uncountable level. The SM counts of 2 days fermented and heat treated sucuk samples increased significantly (P<0.05) until 1 month of storage and then showed a horizontal course. The SM counts of 0 and 1 day fermented and heat treated sucuk samples also showed a horizontal course. The SM counts of traditional sucuk were slightly decreased (P<0.05). Bilenler et al. (2017) reported that the SM counts of 24-hour fermented beef starter culture added sucuk was found as 6.89 log CFU/g, after heat treatment at 70 °C the SM count decreased to 3.63 log CFU/g and after 45 days of refrigerated storage the SM count increased to 3.92 log CFU/g. Similar SM counts were reported by other researchers (Dalmış and Soyer, 2008; Ercoşkun et al., 2010).

Figure 9 shows the TE counts of sucuk samples during production. TE counts showed a decrease from an initial value of 4.54 to <1 log CFU/g on the 6th day and finally <1 log CFU/g in the traditional sucuk. It was not detected in the traditional and heat treated sucuk samples during storage. TE counts in all sausages were determined below 1 log cfu/g.

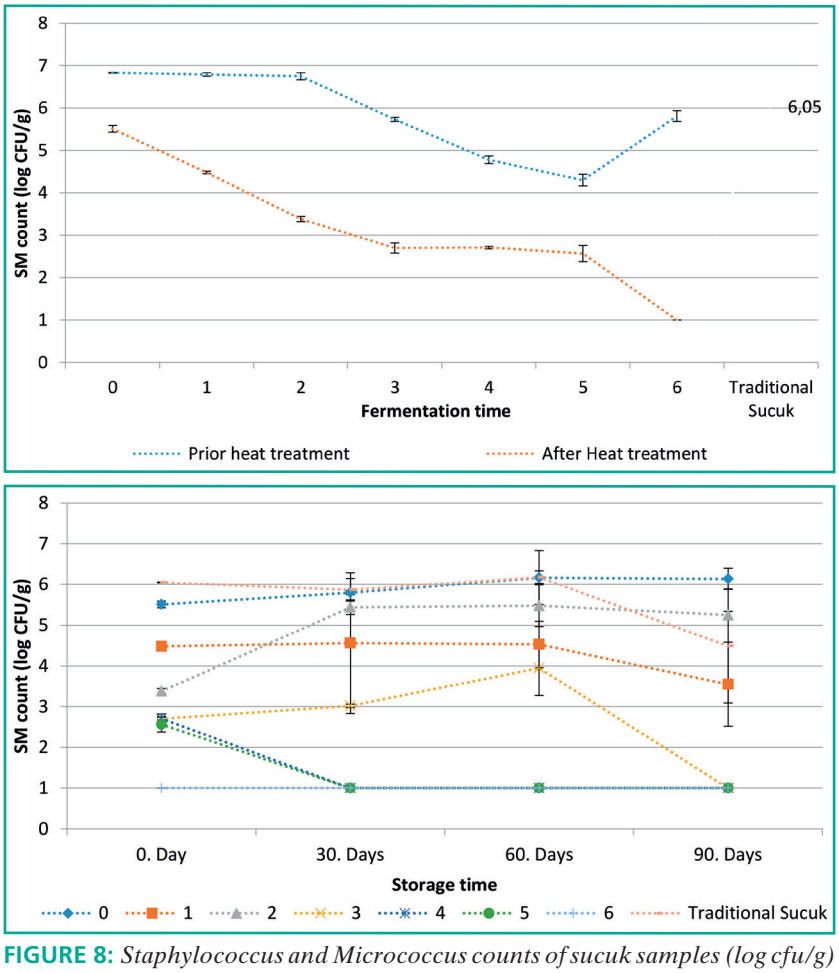

FIGURE 8: *Staphylococcus and Micrococcus counts of sucuk samples (log cfu/g) during production (top) and storage (down) (n:3).*

The results of sensory evaluations are shown in Table 3. Traditional sucuk took the best inner and outer colour scores (P<0.05). On the other hand, the sensory colour scores increased until the 3rd day. After this, while inner colour decreased until the 6th day, the outer colour remained constant (P<0.05). Consistency scores showed an increase and traditional sucuk had consistency scores between 0 and 1 day fermented and heat treated sucuks. Appearance scores increased in the first 3 days and remained constant (P<0.05). Traditional sucuks had the highest scores of odour and taste. However, the flavour scores of traditional sucuk were similar to 4–6 day fermented and heat treated sucuks. Odour, taste and flavour scores of heat treated sucuks increased in the first 3 days of fermentation. Chewiness scores increased in the first 3 days and remained constant in heat treated sucuks (P<0.05). Overall acceptability scores increase until the 4th day of fermentation and traditional sucuk took a score between 3 and 4-day fermented sucuks.

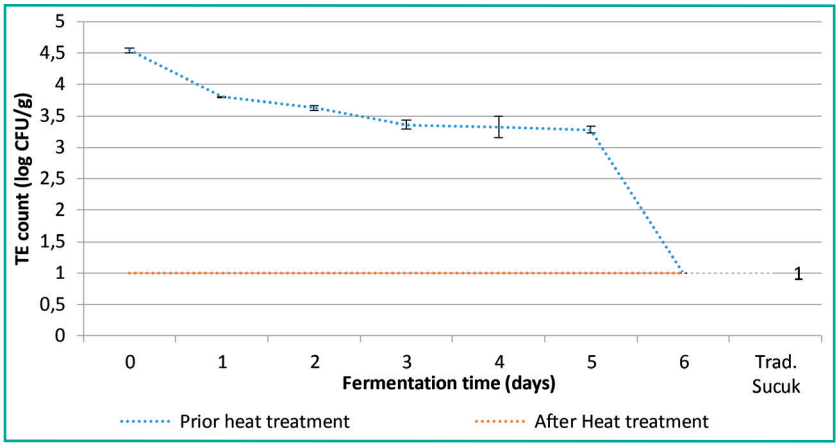

FIGURE 9: *Total Enterobacteriaceae counts of sucuk samples (log cfu/g) during production (n:3).*

The aim of this study was to determine microbiological and physicochemical attributes of sucuks heat-treated at 60°C for 10 minutes with different fermentation intervals. With this study, similar results were obtained for physicochemical, microbiological and sensory properties obtained by heat treatment of sucuk at higher temperatures. In terms of pH and proximate composition analyses, similar results have been observed with the heat treatment applications performed at higher temperatures in the literature. While the free fatty acidity and TBARS values were expected to be lower due to lower temperature heat treatment, again similar results were obtained with the literature. Striking difference in this study was; lesser degradation of nitrosomyoglobin and total haem pigment and higher conversion rate of nitrosomyoglobin compared to heat treatments performed at higher temperatures in sucuk which can be also observed in result of instrumental colour analyses. In the microbiological analysis results of the non-heat-treated sucuk samples during fermentation; the log, stagnation and death stages were clearly seen in the LAB counts, while TMAB counts showed stagnation phase, SM counts and TE counts showed death phase. Decreases in LAB, TMAB and SM counts were observed and TE counts disappeared completely during the heat treatment of sucuk. During the storage of heat-treated sucuk samples, an increase in the number of TMAB, LAB and SM was observed in sausages fermented for less than 3 days, while the numbers of TMAB, LAB and SM for sausages fermented more than 4 days fell below the detectable limit in the first month of storage. *Lactobacillus plantarum* added as starter culture and lactic acid bacteria found in sausage batter produced lactic acid and provided pH decrease. The rapid acidifying starter cultures used in the production of heat treated sucuk is important in terms of microbial destruction during heat treatment. However, *Stapylococcus carnosus* added as starter culture did not live long enough to show the proteolytic and lipolytic activities expected of it. Moreover, according to the sensory panel results, sucuk that were fermented for 3 and more days and then heat treated received higher overall acceptability scores.

Conclusion

Despite the usage of starter cultures, additives and temperature, relative humidity and air velocity conditioning, the food-borne pathogen always poses a risk for traditional sucuk production, more important than technical risks such as shell formation, nitrite and salt migration with water, discoloration, excessive drying on the surface and non-drying inside, sponge formation etc. Mass industrial production increases these risks proportionally to increasing capacity. In order to overcome all these difficulties, heat treatment has become common in sausage production for recent decades. Traditional sausage production is no longer a commercial production. A heat treatment at 68 °C is commonly applied after a short fermentation period of one or two days. Under the conditions of insuffi-

TABLE 3: Sensory scores of the samples.

	Fermentation Time of Heat Treated Sucuks (Days)							Traditional
	0	1	2	3	4	5	6	Sucuk
Outer Colour	3.61 ±0.25 ^{E}	4.27 ±0.42 ^{D}	5.00 ±0.17 ^{C}	5.33 ±0.17 ^{BC}	5.55 ±0.19 ^{B}	5.44 ±0.35 ^{BC}	5.43 ±0.28 ^{BC}	6.94 ±0.26 ^{A}
Inner Colour	3.28 ±0.25 ^{E}	4.04 ±0.19 ^{D}	4.50 ±0.17 ^{BC}	4.83 ±0.17 ^{B}	4.89 ±0.34 ^{B}	4.50 ±0.17 ^{BC}	4.38 ±0.25 ^{CD}	6.89 ±0.26 ^{A}
Consistency	5.44 ±0.35 ^{D}	6.11 ±0.25 ^{C}	6.77 ±0.34 ^{B}	7.61 ±0.25 ^{A}	7.61 ±0.25 ^{A}	7.83 ±0.17 ^{A}	7.83 ±0.33 ^{A}	5.83 ±0.17 ^{CD}
Appearance	4.83 ±0.17 ^{D}	5.33 ±0.33 ^{C}	5.83 ±0.17 ^{B}	6.11 ±0.25 ^{A}	5.66 ±0.17 ^{B}	5.83 ±0.17 ^{AB}	5.78 ±0.25 ^{B}	5.88 ±0.25 ^{AB}
Taste	5.55 ±0.35 ^{D}	6.66 ±0.17 ^{C}	7.44 ±0.35 ^{B}	7.61 ±0.25 ^{B}	7.55 ±0.25 ^{B}	7.66 ±0.17 ^{B}	7.27 ±0.42 ^{B}	8.61 ±0.25 ^{A}
Odour	5.55 ±0.25 ^{E}	5.55 ±0.25 ^{E}	7.44 ±0.26 ^{D}	7.33 ±0.17 ^{D}	7.55 ±0.25 ^{CD}	7.83 ±0.17 ^{BC}	7.88 ±0.25 ^{B}	8.78 ±0.25 ^{A}
Flavour	5.50 ±0.34 ^{E}	6.33 ±0.17 ^{D}	7.00 ±0.17 ^{C}	7.44 ±0.26 ^{B}	7.66 ±0.17 ^{AB}	7.83 ±0.33 ^{AB}	8.00 ±0.17 ^{A}	7.50 ±0.34 ^{B}
Chewiness	5.28 ±0.25 ^{C}	6.61 ±0.25 ^{B}	7.50 ±0.17 ^{A}	7.61 ±0.25 ^{A}	7.55 ±0.25 ^{A}	7.33 ±0.17 ^{A}	7.66 ±0.17 ^{A}	6.22 ±0.42 ^{B}
Overall Acceptability	5.61 ±0.42 ^{D}	6.61 ±0.25 ^{C}	7.38 ±0.25 ^{B}	7.78 ±0.25 ^{B}	8.66 ±0.17 ^{A}	8.50 ±0.44 ^{A}	8.78 ±0.25 ^{A}	7.72 ±0.26 ^{B}

$^{A-E}$ Means in the same raw with different lowercase superscripts are significantly different (P<0.05).
Evaluation on a 10-point scale (1=dislike extremely - 10=like extremely). n:3

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cient fermentation time and high heat treatment temperature, heat treatment destroys the microbial flora including starter cultures and meat enzymes, and therefore, sensory quality problems such as insufficient taste, odour, flavour, colour, texture occur in heat treated products. In the present study, different fermentation intervals and heat treatment temperature of 60 °C were investigated to maintain the specific product characteristics of fermented sucuks. A microbial destruction, which is very similar to the microbial destruction seen at 68 °C, was succeed at 60 °C for 10 minutes. The results revealed that a fermentation time necessary for food safety and quality attributes of the product but physicochemical, microbiological and sensorial properties of heat treated sucuk was different comparing with traditional sucuk.

Conflict of interest

The author declare that he have no known competing financial and occupational interests or personal relationships that could influence the contents or opinions presented in the above-mentioned manuscript.

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