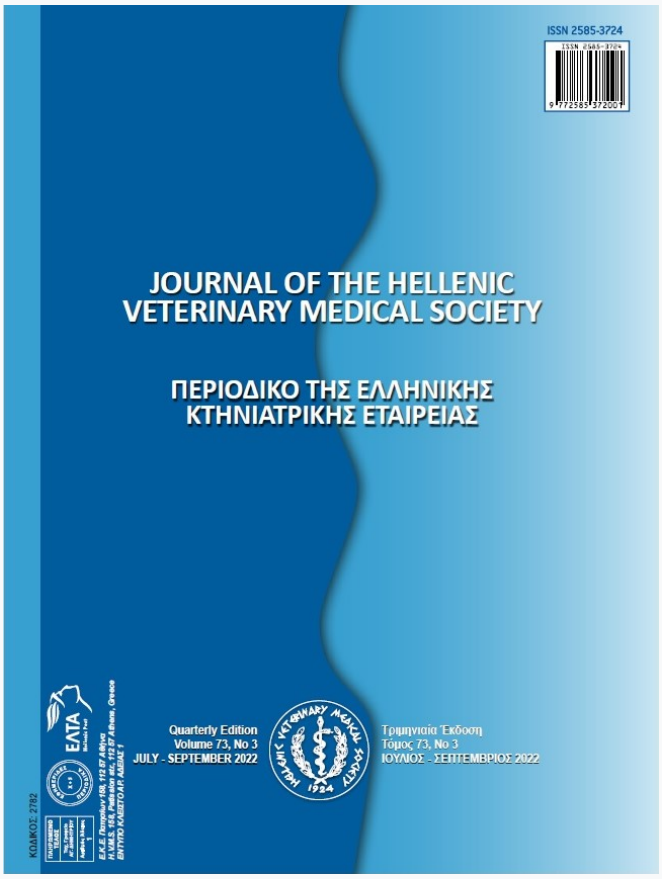
Journal of the Hellenic Veterinary Medical Society

Vol 73, No 3 (2022)



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YÇ Sezer

doi: 10.12681/jhvms.27298

To cite this article:

Sezer, Y. (2022). Effects of different temperatures on the quality characteristics of turkey sausage and changes during storage time. *Journal of the Hellenic Veterinary Medical Society*, *73*(3), 4433–4440. https://doi.org/10.12681/jhvms.27298

J HELLENIC VET MED SOC 2022, 73 (3): 4433-4440
ΠΕΚΕ 2022, 73 (3): 4433-4440

Research article
Ερευνητικό άρθρο

Effects of different temperatures on the quality characteristics of turkey sausage and changes during storage time

Y. Çelebi Sezer

Food Processing Department, Eşme Vocational School, Uşak University, Usak, Turkey

ABSTRACT: This research aims to establish the effects of different thermal treatment temperatures(62°C, 68°C and 75°C) applied to turkey sausages on the physicochemical, microbiological, and textural features of the product and biogenic amine formation during thermal treatment and storage. To this end, three different internal temperatures (62°C, 68°C and 75°C) were applied to turkey sausages fermented for 3 days at 23°C and relative humidity (85%±1). The product's lactic acid bacteria (LAB), *Micrococcus*/*Staphylococcus* growth, pH, residual nitrite, 2-thiobarbituric acid reactive substances(TBARS) and biogenic amine (tyramine, histamine, putrescine, cadaverine, spermidine and spermine) formation were analyzed during thermal treatment and storage (18°C, 20 days). Different internal temperature applications affected LAB growth, residual nitrite, and biogenic amine formation($P<0.05$). While LAB, *Micrococcus*/*Staphylococcus* growth and residual nitrite values decreased significantly during storage($P<0.05$), the amounts of biogenic amines, other than spermidine, increased. Furthermore, no difference was detected in pH and TBARS values($P> 0.05$). The interaction of different internal temperature applications and storage times affected only LAB and biogenic amine amounts. As a result of the study, increasing internal temperature applications caused significant changes in the quality characteristics of turkey sausage during the storage period. Although the LAB valuesdecreased with the increase in the internal temperatures, the biogenic amine amounts during storage increased with increasing internal temperature application. Therefore, thermal treatment at 62°Cfor 5 min is the most suitable method to be used forturkey sausage.

***Keywords*:** turkey sausage, different internal temperatures, biogenic amine, storage

Corresponding Author:
Yasemin Çelebi Sezer, Food Processing Department, Eşme Vocational School, Uşak University Usak, Turkey
E-mail address: yasemincelebisezer@gmail.com

Date of initial submission: 17-06-2021
Date of acceptance: 23-08-2021

INTRODUCTION

Fermentation is one of the oldest procedures which combines microorganisms, meat and technology and is used to preserve foods for a longer period of time, to increase their shelf life, and to obtain a more reliable and high-quality product microbiologically (Nassu et al., 2003; Sakhare and Rao2003; Amit et al., 2017). Traditional fermented sausage is produced by filling minced lamb and/or beef, garlic, salt, sugar, spices, and tail fat in casings (Bozkurt and Erkmen, 2004; Çelebi Sezer 2020). In industrial production, unlike traditional production, the product is subjected to thermal treatment after a short-term fermentation process (Coşkuner, 2002). Heat-processed sausage, which is accepted as a semi-dry fermented sausage variety, is subjected to short-termfermentation, heat processing, and drying operations (Sallan et al. 2020). By preventing the development of foodborne pathogens with thermal treatment, more hygienic and reliable products are obtained, the production time is shortened, production costs are reduced, and the demand for heat-treated sausage has increased due to these reasons (Ercoşkun et al., 2010; Kaban, 2013; Bilenler et al. 2017; Öztürk-Kerimoğlu et al. 2019).

Turkey meat, one of the poultry meat varieties, has a high ratio of unsaturated fatty acids, low cholesterol levels, and sensory properties very close to red meat, which led to an increase in its consumption. Moreover, it is an important raw material due to reasons such as higher meat yield, rapid growth, and higher lean meat ratio according to the nutritional ratio of turkey compared to other animal species from which red meat is obtained (Baggio et al., 2002; Amirkhanov et al., 2017). Turkey meat, which is suitable for the production of many products similar to those produced from red meat, is also used in the production of sausage, also fermented ones. However, due to the higher pH value of traditional fermented sausage made from turkey meat, the presence of important pathogenic microorganisms such as *Salmonella* spp. and *Campylobacter jejuni* can pose a serious public health threat. Moreover, the use of turkey meat in traditional dry fermented sausages without thermal treatment was discussed because the fatty tissue of poultry meat is not suitable for the textural properties of fermented sausage (Santchurn and Collignan2007). Therefore, thermal treatment application is important for product safety (Sallan et al. 2020). Furthermore, the use of a starter culture is very important to obtain better quality and safer products by providing the desired characteristics with the short-term fermentation process applied to this type of sausage (Armutçu et al., 2020). Ensoy et al. (2010) investigated the effects of the use of a starter culture together with heat processing on the biochemical and microbiological attributes of turkey sausages. In many other studies, although thermal treatment was applied in the production of turkey sausage at temperatures varying between 55 °C and 75 °C (Du and Ahn, 2002;Ensoy, 2004;Ensoy et al., 2010;Zouariet al., 2012; Kaban and Bayrak 2015), comparative evaluation of different internal temperature applications during storage was not performed. Moreover, there is no study in the literature exploring the influences of different internal temperatures on the microbiological, physicochemical, and biogenic amine changes of turkey sausage, which are indicators of quality in foods. In this research, the effects of three internal temperatures (62°C, 68°C and 75°C) applied to turkey sausage after short-term fermentation were investigated for the microbiological, physicochemical, and textural features of the product and biogenic amine formation during thermal treatment and the storage period.

MATERIALS AND METHOD

Material

Turkey meat for the experiments was purchased from Bolu Quality Feed Ind. Inc., Turkey. Commercial virgin olive oil, spices, salt, tail fat and sugar were bought from a local market in Osmaniye. A mixture of *Lactobacillus plantarum*, *Pediococcus pentosaceus*, *Staphylococcus carnosus* and *Staphylococcus xylosus* were provided by Biocarna (Wiesby, Germany). Sodium nitrate ($NaNO_3$) and sodium nitrite ($NaNO_2$) were obtained from Merck company.

Turkey Sausage Production and Sampling Procedures

All turkey sausage samples were made in the Food Engineering Laboratory in Osmaniye, Turkey. Turkey meat with tail fat, olive oil, starter culture, spices, salt, clean dry garlic and sugar were used for turkey sausage batter according to these rates; 900 g boneless turkey thigh meat, 200 g tail fat, 20.76 g garlic, 2 g olive oil, 11 g allspice, 11g red pepper, 5.50 g black pepper, 18 g salt, 4.4 g sugar, 5.5 g cumin, 1 g cinnamon, and 0.48 g clove. About 150 mg/kg $NaNO_2$ and 300 mg/kg $NaNO_3$ were used as curing components. Boneless turkey thigh meat was minced and mixed with the remaining all ingredients with the exception of the tail fat. Starter culture was added at about 20 g commercial culture mixture per 100 kg of meat.

Then, turkey sausage batter was stuffed into artificial collagen casings (38 K, Kutluer Food, Turkey) and fermented for 3 days at 23°C and relative humidity (85%±1). Then, three different thermal treatment temperatures were applied to the turkey sausages. Firstly, turkey sausages were heated until the center temperature reached 62 °C, 68 °Cand 75 °C and kept at this temperature for 5 min in an oven (Thermomac, FDO45, Turkey), respectively. Finally, heat-treated turkey sausages were stored at 18°C for 20 days. Turkey sausage production was performed in duplicate.

Firstly, turkey sausages were analyzed on the 0 and 3rd days of fermentation. After that, heat-treated sausages were taken for analysis from the first day with intervals of 10 days during storage. The lactic acid bacteria (LAB), *Micrococcus/Staphylococcus*, *Enterobacteriaceae* counts, pH, 2-thiobarbituric acid reactive substances (TBARS), and biogenic amine formations were determined. All analyses were performed in triplicate.

Microbiological Analysis

A sample of 10 g turkey sausage was homogenized with 90 ml sterile maximum recovery diluent (MRD) solution. LAB, *Micrococcus/Staphylococcus* and *Enterobacteriaceae* counts were performed in triplicate on De Man Rogosa Sharpe Agar (Merck) at 30°C for 3 days, on Mannitol Salt Phenol-Red Agar (Merck) at 30°C for 3 days and on Violet Red Bile Dextrose Agar (Merck) at 30°C for 2 days, respectively (Erkmen, 2000).

Physicochemical Analysis

The pH levels of turkey sausages were analyzed with a pH meter (Thermo Scientific, Orion 2 Star).

Residual Nitrite

The measurement of residual nitrite was carried out by the method of Yetim and Kesmen (2005). Turkey sausage samples homogenized with borax solution and hot distilled water were kept in a boiling water bath for 15 min and Carez 1 (Merck) and Carez 2 (Merck) solution was added. Sample solutions, diluted with distilled water to a volume of 200 ml, were kept at room temperature for 30 min and filtered twice using filter paper (Whatman 42). Griess (Merck) solution was added to the filtrate at the rate of 1/1 and kept at room temperature in the dark for 30 min, then absorbance values were measured at 540 nm against blank.

Lipid Oxidation

TBARS (2-thiobarbituric acid reactive substances) levels of the turkey sausage samples were examined using a spectrophotometer (UV 1800, Shimadzu, Tokyo, Japan). Turkey sausages were homogenized and a 2 g sample was extracted with 0.4 M perchloric acid and centrifuged for 5 min at 1790xg speed. After that, 1 ml of sample and 5 ml TBA reagent were heated in a boiling water bath for 35 min. The absorbance of the sample was compared to a blank at 538 nm (Bozkurt and Erkmen, 2004).

Measurement of Biogenic Amines

Biogenic amines (BA) were extracted from 2.0 g turkey sausage samples with 0.4 M perchloric acid and established as their dansyl derivatives by use of a chromatographic-based method (Bozkurt and Erkmen, 2007). The high-performance liquid chromatography (HPLC) system includes a quadratic gradient pump (Ultimate, 3000 Pump), anionex Ultimate 3000 Diode Array Dedector, an Ultimate 3000 Column Compartment, and a computer containing a Choromomelon package program. The HPLC column was a Spherisorb ODS2, 200 μm and 4.60 mm x 200 mm, (Phenomenex, Torrance, CA, US). The conditions were applied as explained by Çelebi Sezer and Bozkurt (2019).

Statistical Analyses

Two-way analysis of variance (ANOVA) with interaction by the general linear model(GLM) operation was applied to compare averages. When a significant effect ($p< 0.05$) was established by using ANOVA, Duncan's multiple range test was applied to examine which sample groups were distinct from the others. Statistical analyses were completed using SPSS version 17.0.

RESULTS AND DISCUSSION

Microbiological Analysis

As a result of the study, a significant increase was determined in the LAB count of turkey sausage during fermentation ($P< 0.05$), and it was found to be 8.13 log cfu/g (Table 1). This increase may be related to fermentation temperature, relative humidity change, the initial load of meat, pH changes, and starter culture addition (Bozkurt and Erkmen, 2007; Küçükkaya et al. 2020). Furthermore, as a result of the thermal treatment application, a decrease ($P< 0.05$) in the LAB count varying between 2 and 3 log was observed (Table 1). In similar studies, significant decreases

Table 1. Changes in LAB, *Micrococcus/ Staphylococcus*, pH, residual nitrite and TBARS values of the turkey sausages during fermentation and after thermal treatment (62, 68 and 75°C) (mean ± SD)

		LAB (log cfu/g)	*Micrococcus/ Staphylococcus (log cfu/g)*	pH	Residual Nitrite (mg/kg)	TBARS (mg MDA/kg)
Turkey sausage dough		6.5±0.08b	6.35±0.02a	6.05±0.02a	150±5.09a	0.60 ± 0.05a
Fermentation		8.13±0.11a	6.4±0.03a	5.26±0.03c	32.23±1.32b	0.85 ± 0.12b
Heat Processing Degrees (°C)	62	6.1±0.08c	5.91±0.04b	5.32±0.01b	13.12±0.74c	1.25± 0.04c
	68	5.86±0.08d	5.9±0.02b	5.34±0.02b	10.15±0.52d	1.23± 0.05c
	75	5.15±0.07e	5.88±0.02b	5.35±0.04b	8.89±0.45e	1.26± 0.03c

Note: a-e: Different letters indicate statistical difference (p < .05) in the each row.SD: standard deviation

were observed in the LAB count after heat processing (Dalmış and Soyer, 2008; Erçoşkun et al., 2010; Kaban and Bayrak, 2015). Different internal temperature applications had a significant effect on LAB growth (P< 0.05). The maximum decrease was detected with the application of 75°C internal temperature during thermal treatment. On the other hand, the LAB count reduced significantly during the storage process for turkey sausage (P< 0.05) (Fig. 1.a). At the same time, the interaction of different internal temperature applications and storage times had a significant effect on LAB(P< 0.05).

During short-term fermentation before thermal treatment, there was no significant increase in the *Micrococcus/Staphylococcus* count (P> 0.05) (Table 1). This originates from the fact that the acidity of the environment restricts the growth of microorganisms due to the pH decrease rapidly of lactic acid bacteria by fermentation (Sanz et al. 1997). Likewise, it was stated in many studies that acid-sensitive *Micrococcus/ Staphylococcus* bacteria show poor growth during fermentation (Lücke, 1985; Kaban and Kaya 2009; Kaban and Bayrak, 2015). Thermal treatment affected the *Micrococcus/Staphylococcus* count (P< 0.05) and caused a decrease of approximately 0.5 log (Table 1). In different research performed on turkey sausage, it was noticed that heat processing had a significant effect on the catalase-positive cocci count (Kaban and Bayrak, 2015). Similar to the studies performed by Yılmaz (2016), Öz et al. (2018), and Armutçu et al. (2020), different internal temperature applications did not affect *Micrococcus/Staphylococcus* growth. The *Micrococcus/Staphylococcus* count decreased significantly during the storage process of turkey sausage(P<0.05) (Fig 1.b). Furthermore, the interaction of different internal temperature applications and storage times did not have a significant effect on the *Micrococcus/Staphylococcus* count(P> 0.05).

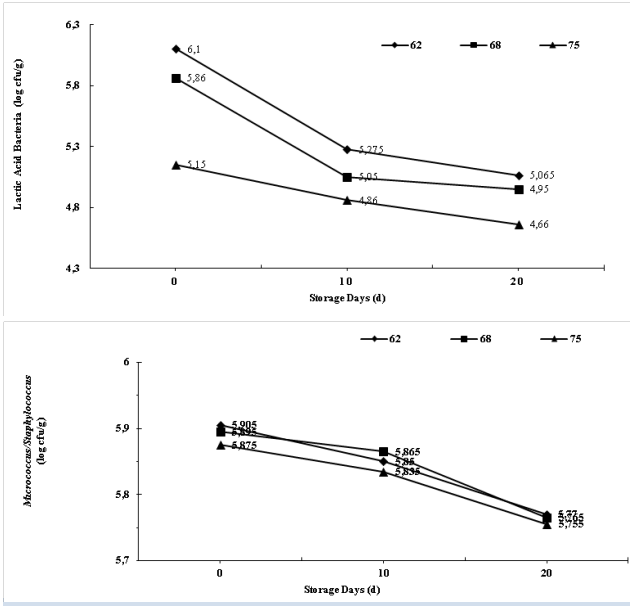

Fig 1: Changes in (a) LAB and (b) *Micrococcus/ Staphylococcus* counts at different temperatures (62, 68 and 75°C) thermally treated turkey sausages during storage

At the end of short-term fermentation, the *Enterobacteriaceae* count was observed to be approximately 3 log cfu/g, but the count decreased below the detectable level (<2 log cfu/g) after the thermal treatment (62°C, 68°Cand75°C). In a similar study, *Enterobacteriaceae* was easily inhibited in sausage by thermal treatment (Kaban and Bayrak, 2015).

pH

The average pH level, which was found to be 6.05± 0.02 in the sausage batter,was reduced to 5.26±0.03 at the end of fermentation (P < 0.05) (Table 1). This decrease may be due to acid-producing bacteria, especially those producing lactic acid (Erçoşkun et al., 2010). An increase in pH values was observed due to the protein denaturation after heat processing (Erçoşkunet al., 2010) (Table 1). Although there was

a slight reduction in pH levels during storage, it was not statistically significant (P> 0.05). Likewise, the interaction of different internal temperature applications and storage times had no effect on the pH level (Table 2). According to the results obtained from similar studies, the most dominant period in terms of pH in heat-processed sausage was fermentation and the fast reduction in pH observed during this period contributed significantly to product safety (Kaya and Kaban, 2016; Armutçu et al., 2020).

Residual Nitrite

The residual nitrite level decreased from 150 mg/kg to 32.23 mg/kg during fermentation (P < 0.05) (Table 1). This may be associated with the conversion of nitrite to nitrate or the reaction of nitrite with muscle proteins during fermentation (Pérez-Alvarez et al., 1999; Kurt and Zorba, 2010). The decrease in the nitrite level observed in sausage was similarly reported in many studies (Alley et al., 1992; Johansson et al., 1994; Bozkurt and Erkmen, 2004). As temperatures applied during thermal treatment increased, the residual nitrite values in the samples decreased statistically significantly (P< 0.05). In a similar way,this was reported in different studies (Soyutemiz et al. 2004 and Kurt and Zorba 2010). Although there was an increase in the residual nitrite levels of sausage during storage(P<0.05), the interaction of different internal temperature applications and storage times had no effect (P> 0.05) on the residual nitrite value (Table 2). According to the criteria of European countries, the residual nitrite value in sausages is limited to <15 mg/kg (Wirth, 1986). According to these criteria, turkey sausage is at an acceptable level due to low nitrite residues.

Lipid Oxidation

The TBARS value of 0.60 ± 0.05 mg MDA/kg in the sausage batter increased significantly at the fermentation stage (P < 0.05) and reached the level of 0.85±0.12 mg MDA/kg (Table 1). This increase may be related to the partial dehydration of meat proteins and the oxidation of unsaturated fatty acids in meat (Yang et al. 2017). The effects of fermentation time on TBARS values are consistent with the results of many studies (Bozkurt and Erkmen, 2004; Bozkurt, 2007). Lipid oxidation can easily occur in heat-treated poultry meat with a high percentage of unsaturated fatty acids (Beltran et al., 2003). Although the TBARS values of turkey sausage increased statistically significantly with thermal treatment application(P < 0.05), thethree temperatures appliedhad no effect on TBARS levels. Likewise, it was reported in different studies that thermal treatment application increases the TBARS value (Ercoşkun et al. 2010; Çakır et al. 2013). No difference was detected in the TBARS levels of turkey sausage during storage.

Table 2. Changes in pH, residual nitrite (mg/kg) and TBARS (mg MDA/kg) levels of different degrees (62, 68 and 75°C) heat treated turkey sausages during storage (mean ± SD)

		pH			Residual Nitrite (mg/kg)			TBARS (mg MDA/kg)		
Storage Days (SD)		0	10	20	0	10	20	0	10	20
Heat Processing Degrees (°C) (HPD)	62	5.32±0.01a,A	5.3±0.19a,A	5.28±0.10a,A	13.125±0.74c,A	13.835±0.05b,A	14.555±0.45a,A	1.25 ± 0.04a,A	1.27± 0.05a,A	1.29± 0.07a,A
	68	5.34±0.02a,A	5.29±0.18a,A	5.27±0.11a,A	10.155±0.52c,B	10.885±0.36b,B	11.865±1.20a,B	1.23 ± 0.05a,A	1.22± 0.04a,A	1.28± 0.08a,A
	75	5.35±0.04a,A	5.32±0.20a,A	5.28±0.08a,A	8.895±0.45c,C	9.185±0.22b,C	10.55±1.50a,C	1.26± 0.03a,A	1.25± 0.03a,A	1.29± 0.09a,A
SD*HPD		NS			NS			NS		

Note: a-e: Different letters indicate statistical difference (p < .05) in the each row. A-E: Different letters indicate statistical difference (p < .05) in each column. NS: not significant, SD: standard deviation.

Table 3. Changes in biogenic amine values (mg/kg) of the turkey sausages during fermentation and after thermal treatment (62, 68 and 75°C) (mean ± SD)

			Heat Processing Degrees (°C)		
Biogenic Amines	Turkey Sausage	Fermentation	62	68	75
Tyramine	N.D.	78.09± 7.05d	107.49± 11.98c	114.18± 9.05b	116.83± 1.15a
Histamine	N.D.	50.68± 5.05d	70.35± 7.16c	74.73± 10.55b	76.47± 0.75a
Putrescine	N.D.	156.98± 11.08d	222.69± 10.05c	236.55± 16.05b	242.05± 2.05a
Cadaverine	N.D.	23.56± 1.05d	38.93±1.05c	41.36± 5.05b	42.32± 145a
Spermine	15.89±0.25d	16.87±1.25d	27.89± 2.05c	29.63± 0.99b	30.32± 1.35a
Spermidine	22.33±1.25d	23± 1.34d	30.29± 3.05c	29.10± 1.05b	25.57± 1.25a

Note: a-e: Different letters indicate statistical difference (p < .05) in the each row. ND: not detected, SD: standard deviation.

Biogenic Amine

No biogenic amine, other than spermine and spermidine, was detected in turkey sausage batter. Moreover, the Roig-Sagues and Eerola (1997) method was applied to the starter cultureused, and this method didn't influence on biogenic amine production under in vitro conditions. Six biogenic amines in total, including tyramine, cadaverine, histamine, putrescine, spermidine, and spermine, were detected in turkey sausage at the end of short-term fermentation (Table 3). At the end of fermentation, the amounts of tyramine, histamine, putrescine, and cadaverine increased significantly. This can be explained by the high water activity and suitable pH values of turkey sausage, which causes the rapid growth of aerobic bacteria in the early stages of fermentation (Kim et al., 2019; Jia et al., 2020). Furthermore, some researchers reported that with the increase in the aerobic bacteria and LAB counts, the formation of tyramine and putrescine increased (Bover-Cid et al. 2001; Kurt and Zorba, 2009). The tyramine, histamine, putrescine, and cadaverine contents of turkey sausage at the end of fermentation were78.09, 50.68, 156.98, and 23.56 mg/kg, respectively. The increase in the spermidine and spermine content during fermentation was found to be insignificant. This can be explained by the fact which spermine and spermidine are raw material-sourced polyamines that cannot be controlled by amino acid decarboxylation bacteria (Hernandez-Jover et al., 1997). Likewise, no difference was detected in the spermine and spermidine levels during fermentation in the studies conducted by Zhang et al. (2019) and Wang et al. (2020).

Thermal treatment significantly affected the biogenic amine amounts in turkey sausage. Biogenic amine formation increased as the temperatures applied during thermal treatment increased. This increase may be related to the thermal decarboxylation of free amino acids caused by the applied thermal treatment (Spizzirri et al., 2019). Likewise, storage time had a significant effect on biogenic amine amount ($P < 0.05$) (Table 4). In a similar way, the interaction of different internal temperature applications and storage times had an effect on biogenic amine values($P < 0.05$). Tyramine and histamine are the most toxicologically important biogenic amines, and after thermal treatment, tyramine was found in the range of 107.49-116.83 mg/kg and histamine in the range of 70.35-76.47 mg/kg, respectively. During storage, the tyramine and histamine contents increased significantly ($P < 0.05$) and reached 118.79-141.98 mg/kg and 77.75-92.92 mg/kg, respectively (Table 4). On the other hand, in a different study, the histamine value of turkey sausage was determined to be 263 mg/kg after 28 days of storage at 4°C (Rabie et al., 2014). Shalaby (1996) reported that the accepted value of tyramine in food products was 100-800 mg/kg, while 1080 mg/kg was toxic. The European Food Safety Authority (EFSA) states that due to the toxicological effect of histamine, the maximum daily intake of histamine is 100 mg/kg. The histamine and tyramine levels of turkey sausage obtained in the study were found to be at acceptable levels (Nout, 1994).

The cadaverine and putrescine content, which can increase the toxicity of tyramine and histamine due to the inhibition of detoxifying enzymes in turkey meat (Jia et al., 2020; Rabie et al., 2014), increased during storage while they were 38.93-42.32 mg/kg and 222.6-242.05 mg/kg after thermal treatment and reached 43.03-51.43 mg/kg and 246.11-294.14 mg/kg, respectively ($P < 0.05$) (Table 4). Similarly, in astudy performed by Rabie et al. (2014), putrescine concentration was determined to be 285 mg/kg at the end of storage of turkey sausage. However, the concentration of putrescine was found to be higher than the amounts determined by Ciuciu et al. (2014) (ranging from 26 to 49 mg/kg) and Ikonic et al. (2013) (18.5 mg/kg). *Enterobacteriaceae* have a significant effect on cadaverine formation($P < 0.05$) (Suzzi and Gardini, 2003; Shalabay, 1996). The amount of cadaverine was reported in other studies in the range of 37 to 110 mg/kg, in parallel with this study (Ikonic et al. 2013;

Table 4. Changes in biogenic amines values (mg/kg) of different degrees (62, 68 and 75°C) heat treated turkey sausages (mean ± SD)

		Tyramine			Histamine			Putrescine			Cadaverine			Spermine			Spermidine		
Storage Days (SD)		0	10	20	0	10	20	0	10	20	0	10	20	0	10	20	0	10	20
Heat Processing Degrees (°C) (HPD)	62	107.49± 11.98c,C	112.10± 10.99b,C	118.79± 7.66a,C	70.35± 7.16c,C	73.37± 8.06b,C	77.75± 7.22a,C	222.69± 10.05c,C	232.25± 10.05b,C	246.11± 12.67a,C	38.93± 1.05c,C	40.61± 2.05b,C	43.03± 1.05a,C	27.89± 2.05c	29,09± 2.25b	30.83± 2.77a,C	30.29± 3.05c,A	26.19± 2.55b,A	25.15± 2.15a,A
	68	114.18± 9.05c,B	116.49± 9.98b,B	135.17± 10.98a,B	74.73± 10.55c,B	76.24± 6.86b,B	88.47± 6.11a,B	236.55± 16.05c,B	241.33± 10.05b,B	280.04± 11.34a,B	41.36± 5.05c,B	42.19± 1.05b,B	48.96± 3.69a,B	29.63± 0,99c	30.23± 3.05b	35.08± 2.54a.B	29,10± 1.05c.B	25.08± 2.05b,B	24.58± 2.85a,B
	75	116.83± 1.15c,A	121.68± 8.98b,A	141.98± 13.13a,A	76.47± 0.75c,A	79.64± 5.44b,A	92.92± 8.25a,A	242.05± 2.05c,A	252.08± 10.05b,A	294.14± 8.68a,A	42.32± 1.45c,A	44.07± 1.05b,A	51.43± 4.25a,A	30.32± 1.35c	31,57± 2.95b	36.84± 2.05a,A	25.57± 1.25c,C	24.13± 2.11b,C	23.14± 2.23a,C
SD*HPD		*			*			*			*			*			*		

Note: a-e: Different letters indicate statistical difference ($p < .05$) in the each row. A-E: Different letters indicate statistical difference ($p < .05$) in each column.SD: standard deviation., *: $P < .05$.

Ciuciu et al. 2014; Coloretti et al. 2014). In general, the spermidine concentrations of turkey sausage decreased significantly during storage. This may be related to the synthesis of spermine from spermidine (Bodmer et al., 1999; Rabie et al., 2014). Spermine concentration increased significantly during storage and reached levels of 30.83-36.84 mg/kg. Similar to our study, in a study performed by Rabie et al. (2014), it was reported that the spermidine concentration decreased during the storage of turkey sausage, but the spermine concentration increased.

CONCLUSION

Different internal temperatures (62, 68 and75°C) were applied to turkey sausage for thermal treatment after short-term fermentation, and the product quality characteristics were monitored during storage. The maximum decrease in LAB count was observed in sausage, especially at 75 °C. During thermal treatment, the increase in temperature reduces the residual nitrite content ($P<0.05$). Although the TBARS and pH levels of sausage increased significantly during the thermal treatment process, various temperatures applieddid not affect TBARS and pH values. Moreover, as the internal temperature increased, biogenic amine formation increased. During storage, an increase in the residual nitrite, tyramine, histamine, cadaverine, putrescine, and sperm contents was detected in turkey sausage ($P<0.05$). The LAB and *Micrococcus/Staphylococcus* counts decreased significantly ($P<0.05$) during storage of turkey sausage. Furthermore, no difference was detected in the pH and TBARS values of turkey sausage during storage. The interaction of different temperatures appliedand storage times was effective only on LAB and biogenic amine amounts. According to these results, it was observed that various internal temperature degrees used during heat processing after short-term fermentation caused significant changes in the quality characteristics of turkey sausage during the storage period. As temperatures applied during thermal treatment increased, the LAB values in the samples decreased. However, since the amount of biogenic amines increases during storage with the increase in the internal temperature, it is recommended to apply low-temperature (62°C 5 min) thermal treatment for turkey sausage.

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