Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.81321

An evaluation of the physicochemical and microbiological characteristics and the hygienic status of naturally fermented camel sausages (sucuks)

Azim ŞİMŞEK[1]*

Abstract

The objective of this study was to determine the physicochemical and microbiological characteristics of fermented camel sucuks and their hygienic status. In order to determine the hygienic status of sucuks, the study investigated the presence of *Salmonella* spp. and *Listeria monocytogenes,* and carried out counts of *Escherichia coli*, *Bacillus cereus* and *Staphylococcus aureus*. Analyses were performed on 40 sucuks collected from different production and retail outlets in the Aydın province of Turkey. The physicochemical characteristics of the samples were generally within legal limits (except for the pH results). *S. aureus* and *B. cereus* were detected in 9 (22.5%) and 24 (60%) of sucuks, respectively. The counts of *B. cereus* in 9 sucuks and *S. aureus* in 5 sucuks were found to have exceeded the acceptable limits. *E. coli* counts were below the detection limit in all sucuks. *Salmonella* spp. and *L. monocytogenes* were not detected in any of the sucuks. The pH was negatively correlated with the counts of lactic acid bacteria and positively correlated with the pathogenic bacteria counts. The fat content had a significant effect on TBARS, cholesterol, energy and color values. Study results demonstrated that some sucuks were of insufficient hygienic quality and may have posed a hazard to consumer health.

Keywords: fermented sausage; camel meat; consumer health; quality characteristics.

Practical Application: Basic features and hygienic status of fermented camel sucuks were investigated. Although the sucuk characteristics were generally within the legal limits, there was no standardization among products. The hygienic quality of some sucuks was insufficient.

1 Introduction

Meat and meat products are defined as safe when they are suitable for consumption in terms of physical, chemical and microbiological properties. Since meat contains sufficient levels of nutrient components necessary for the growth of microorganisms, many pathogenic and spoilage microorganisms grow in the meat if hygienic processing techniques are not applied. Foodborne diseases mostly occur due to unhygienic food processing. Foodborne infections or intoxications are diseases resulting from the ingestion of foods containing pathogenic microorganisms, or toxins produced by microorganisms (Rajkovic et al., 2020). Bacteria are the main reason for reported foodborne infections or intoxication cases worldwide, and the most prevalent reasons for these types of foodborne diseases are *Staphylococcus aureus*, *Listeria monocytogenes, Salmonella* spp., *Bacillus cereus, Campylobacter jejuni, Clostridium botulinum, Clostridium perfringens* and *Escherichia coli* (Ducic et al., 2016; Rajkovic et al., 2020). The World Health Organization (WHO) has stated that unsafe foods containing harmful bacteria, viruses, parasites or chemical substances cause more than 200 diseases. Worldwide, 420.000 people die every year because of foodborne diseases. Therefore, unsafe foods are emerging as a national and global problem in terms of public health and economic status (World Health Organization, 2015). Field studies on food safety are performed in order to evaluate the hygienic quality and physicochemical characteristics of food products. As a result of these studies, many people are informed about the physicochemical characteristics, microbiological quality and hygienic status of meat products consumed by purchasing from retail markets, small-scale manufacturers and fast-food restaurants.

Camel meat has important potential in terms of health and nutrition for humans due to its rich nutritional contents (Kadim et al., 2008). The composition of camel meat is influenced by the breed type, sex, age, type of nutrition and environmental conditions. Camel meat has a higher moisture content (70 to 77%) and a similar protein content (17.0 to 23.7%) to meats obtained from different animal species such as beef, sheep, goats and chicken (Kadim et al., 2008). Camel meat has lower intramuscular fat (1.1 to 6.2%) and cholesterol levels than other meat animals. In addition, it has a relatively higher percentage of polyunsaturated fatty acids (18.6%) in comparison to beef (8.8%) (Maqsood et al., 2016). The amino acid and mineral contents of camel meat are generally higher than beef due to the lower levels of intramuscular fat content. It is also a good source of vitamins, particularly the vitamin B complex. Camel meat is used in the production of meat products such as burgers, patties and sausages, which has increased the added value of camel meat in recent years (Ayyash et al., 2019).

Received 09 Sept., 2021
Accepted 10 Jan., 2022
[1] *Department of Food Processing, Egirdir Vocational School, Isparta University of Applied Sciences, Isparta, Turkey*
*Corresponding author: azimsimsek@isparta.edu.tr

Sucuk (Turkish dry fermented sausage) is a traditional and very popular meat product that is widely consumed in Turkey. Fermented sucuk is manufactured using two different techniques including a traditional method under natural climatic conditions or industrially under controlled temperature (18 to 24 °C) and humidity (90 to 80%) conditions (Erkmen & Bozkurt, 2004). The product formulation of traditionally manufactured fermented sucuk in comparison to industrial production varies greatly by region. The hygienic quality of these products is related to the type of manufacture and the processing conditions. Traditional sucuk production is generally carried out by small-scale manufacturers, butchers or retailers under poorer and uncontrolled processing conditions. These products may also pose a hazard to the consumer and public health due to the use of raw materials or ingredients of poor hygienic quality (Güven et al., 2006). Therefore, in this study, it was firstly aimed to investigate the hygienic status and microbiological quality of fermented camel sucuks in terms of consumer health. In addition, the physicochemical characteristics of camel sucuks were also determined, and the study results were evaluated by comparison to the Turkish Food Codex. A secondary aim was to determine the correlations among physicochemical or microbiological characteristics.

2 Materials and methods

2.1 Materials

A total of forty samples of fermented camel sucuks were collected over two different time periods (during 2018) from different production and retail outlets in the Aydın province of Turkey. The sucuk samples were obtained aseptically, put into sterile polyethylene bags and immediately transported to the laboratory in a cooling box. Microbiological analyses of samples were performed within 12 h. The sucuks were stored at 4 °C until the physicochemical analyses were carried out. Physicochemical analyses were performed within 5 days of sample collection.

2.2 pH, water activity (a_w) and color analyses

The pH values of the sucuks were measured in homogenates using a benchtop pH/ORP meter (HI 2211, Hanna Instruments, Woonsocket, RI, USA) according to the method described by Ruiz-Capillas et al. (2012). A CIE Lab Color System was used to measure color values (L^*: lightness, a^*: redness and b^*: yellowness). Color measurements were conducted using a Minolta Colorimeter (Model CR-200, Illuminant D65, Minolta corp., Ramsey, NJ, U.S.A.). The hue angle and chroma (saturation index) values were calculated using the a^* and b^* values according to the following formulas (Hernández-Hernández et al., 2009); hue = $\tan^{-1}(b/a)$ and chroma = $(a^2 + b^2)^{1/2}$. The water activity (a_w) of samples was measured in duplicate using a Novasina LabSwift-a_w (Switzerland) at 25 °C.

2.3 Determination of chemical composition, cholesterol and TBARS (thiobarbituric acid reactive substances) levels

Moisture (950.46), fat (991.36), protein (992.15) and ash (920.153) contents were determined with respect to the Association of Official Analytical Chemists (1997) procedures. The salt (NaCl) content was determined using the titration method of Mohr (Papadima et al., 1999). Total carbohydrate contents were calculated by taking into account the difference according to the following formula (Schakel et al., 1997); carbohydrate content (%) = 100 – (moisture (%) + protein (%) + fat (%) + ash (%)). The calculation of energy values (kcal/100 g) were performed in accordance with the Atwater method (Schakel et al., 1997). According to this method, protein (4 kcal/g), fat (9 kcal/g) and carbohydrate (4 kcal/g) were used as the Atwater factors to calculate the energy values on the basis of a 100 g portion. The lipid oxidation level (TBARS) was determined with respect to the extraction procedure as described by Sørensen & Jørgensen (1996), and the TBARS results were calculated with the equation obtained from a calibration curve prepared from 1,1,3,3-tetraethoxypropane (TEP; Sigma-Aldrich, Germany) and expressed as mg MDA/kg samples. The cholesterol content was determined according to the spectrophotometric method as stated by Rudel & Morris (1973). Cholesterol levels were calculated using the calibration curve prepared from 3β-Hydroxy-5-cholestene (C8667; Sigma-Aldrich, Germany) and expressed as mg/100 g samples.

2.4 Microbiological analyses

The total aerobic plate count (APC), total coliforms, yeasts and molds, *Lactobacillus* spp., *Streptococcus-Lactococcus* spp., *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus* counts for the camel sucuks were determined and expressed as log CFU/g of the sample. In addition, the presence of *Salmonella* spp. and *Listeria monocytogenes* was also investigated. To count the APC, coliforms, yeasts and molds, *Lactobacillus* spp., *Streptococcus-Lactococcus* spp., a separate sample (10 g) was aseptically taken and placed into a sterile stomacher bag, and homogenized in 90 mL of physiological saline solution (PSW) containing 0.85% (w/v) NaCl (Merck, 106406) using a stomacher blender (Biobase BK-SHG04, China) for 2 min. Serial decimal dilutions were prepared using the PSW. APC counts were determined using the spread-plate technique and inoculated with 0.1 mL of the appropriate dilutions on plate count agar (PCA, Merck) and incubated at 30 °C for 48 h. Coliform counts were counted on eosin methylene blue (EMB, Merck) agar after incubation at 37° C for 48 h. The numbers of yeasts and molds were counted on potato dextrose agar (PDA, Merck) acidified with sterile lactic acid (pH 3.5) after 5 days of incubation at 25 °C (Casquete et al., 2012). The counts for *Lactobacillus* spp. and *Streptococcus-Lactococcus* spp. were performed by using the double layer technique on de Man, Rogosa and Sharpe (MRS, Merck) agar and M17 agar (Merck), respectively (Comi et al., 2005). All plates were counted after incubating at 30 °C for 72 h.

For counts of *E. coli*, *S. aureus* and *B. cereus*, each separate sample (25 g) was aseptically taken and placed into a sterile stomacher bag, and homogenized in 225 mL of sterile 0.1% peptone water (Merck) using a stomacher blender (Biobase BK-SHG04, China) for 2 min. Serial decimal dilutions were prepared using 0.1% peptone water. The *E. coli* counts were performed on Tryptone Bile X-glucuronide (TBX, Merck) agar incubated at 44 °C for 24 h. *E. coli* colonies with typical brilliant bluish-green colors on the plates were counted. The counts of *S. aureus* were carried out using Baird Parker Agar (BPA, Merck)

supplemented with egg yolk tellurite (Merck). The plates were incubated at 37 °C for 48 h. *S. aureus* colonies with a typical black appearance surrounded by a clear zone on plates were counted and confirmed by a coagulase test (Blaiotta et al., 2004). *B. cereus* counts were determined with respect to the spread-plate technique using mannitol egg yolk polymyxin agar (MYP, Merck), and the plates for enumeration were incubated at 30 °C for 24 h. The identification of typical colonies was carried out using a hemolysis test (Güven et al., 2006).

The presence of *Salmonella* spp. was examined with respect to the International Standardization Organization (ISO 6579-1:2017) method (International Organization for Standardization, 2017a). Biochemical confirmation of *Salmonella* spp. was carried out using an API 20E test kit (BioMerieux, France). The isolation of *L. monocytogenes* was performed according to the ISO 11290-1:2017 procedure (International Organization for Standardization, 2017b). An API *Listeria* kit (BioMerieux, France) was used for the identification of *L. monocytogenes*.

2.5 Statistical analysis

The study results were evaluated by descriptive statistics using SPSS 18.0.0 software (SPSS Inc., Chicago, USA). The relationships among physicochemical or microbiological characteristics were examined by Pearson's linear correlation analysis with the statistical software package mentioned above. The physicochemical and microbiological analysis results in terms of correlation analyses were analyzed separately. Moreover, microbiological analysis results were evaluated by including pH and a_w results. The microbiological analyses results were converted to Log CFU/g for statistical analysis. The significance levels of correlation coefficients were evaluated at the levels of $p < 0.01$ and $p < 0.05$.

3 Results and discussion

3.1 pH, a_w and color results

The pH, a_w and color results of the camel sucuks are shown in Table 1. The average pH value (within the range) of sucuks produced with camel meat was 5.71 ± 0.20 (5.28 to 6.03). According to the Turkish Food Codex (Turkey, 2012), the pH value is required to be lower than 5.40 for fermented sucuks. In this study, it was determined that 10 (25%) of sucuks complied with the pH limit value specified by the Turkish Food Codex (Turkey, 2012). In addition, the pH values of 30 (75%) sucuks ranged from 5.40 to 6.03. Comi et al. (2005) defined the naturally fermented sausages as low acidity products with a final pH range from 5.3 to 6.2. El Adab et al. (2020) stated that the pH values of dry fermented camel sausage without starter culture decreased from 6.22 to 5.79 during 14 days of ripening. On the other hand, Ayyash et al. (2019) stated that pH values of fermented camel sausages ranged between 5.18 and 5.38. In addition, Kök et al. (2006) reported that the average pH value of camel sausages was 6.00. These differences in pH values obtained in the present and previous studies may be explained by the differences in initial meat pH, the use of a starter culture or not, fermentation time and product formulations. Pearson's correlation test demonstrated

Table 1. pH, water activity (a_w) and color results of fermented camel sucuks (n=40).

	Mean ± SD[1]	Minimum	Maximum
pH	5.71 ± 0.20	5.28	6.03
Water activity (a_w)	0.904 ± 0.015	0.872	0.932
L^*	48.55 ± 2.52	44.27	53.59
a^*	21.35 ± 2.18	15.94	23.95
b^*	13.67 ± 1.48	11.07	15.96
Chroma	25.38 ± 2.37	19.42	28.62
Hue angle	32.68 ± 2.65	28.62	36.03

[1]SD: Standard deviation.

that there was a good negative correlation ($r = -0.746$, $p < 0.01$) between the pH and *Lactobacillus* spp. counts. In addition, there was a weak negative correlation between the pH and APC ($r = -0.277$, $p < 0.05$). Similarly, Koutsopoulos et al. (2008) reported that a high negative correlation coefficient ($r = -0.999$) was found between the LAB count and the pH value of the low-fat fermented sausages. Similar results were also reported by Ambrosiadis et al. (2004) and Baka et al. (2011).

In the present study, the average a_w level (within the range) of camel sucuks (Table 1) was 0.904 ± 0.015 (0.872 to 0.932). In addition, a_w levels in only 13 (32.5%) of the sucuks were lower than 0.900. Ayyash et al. (2019) reported that the a_w values of fermented camel sucuks ranged from 0.901 to 0.970. Kargozari et al. (2014) noted that the a_w levels of camel sucuks changed from 0.830 to 0.960 during the ripening period. The great variations observed among a_w levels may have been due to the differences in product formulations, fermentation time and conditions.

According to the Pearson's correlation analysis (Table 2), there were significant relationships ($p < 0.01$) between the a_w and the pH, moisture, salt, fat and ash content with coefficients of 0.661, 0.635, –0.458, –0.421 and –0.323, respectively. These results are in agreement with the findings of Papadima & Bloukas (1999) who noted that a_w levels decreased with increasing salt and fat contents in sausages. Similarly, Ambrosiadis et al. (2004) reported that the a_w levels were significantly positively correlated with moisture content and negatively correlated with ash and fat content in sausages.

The color results (Table 1) for camel sucuks had L^*, a^*, b^*, chroma and hue angle values of about 48.55 ± 2.52 (44.27 to 53.59), 21.35 ± 2.18 (15.94 to 23.95), 13.67 ± 1.48 (11.07 to 15.96), 25.38 ± 2.37 (19.42 to 28.62) and 32.68 ± 2.65 (28.62 to 36.03), respectively. Mejri et al. (2017) reported that the L^*, a^* and b^* values of fermented camel sausages were 43.43, 17.45 and 17.82, respectively. Maqsood et al. (2016) stated that the color value averages of camel sausages were 44.83 for L^* values, 6.58 for a^* values and 16.45 for b^* values. It has been stated that the color values of meat products are affected by several factors such as moisture and fat content, free water, oxidation and ingredients added to the product (Lorenzo et al., 2017; Mejri et al., 2017).

The Pearson's correlation analysis demonstrated that there was a significant relationship ($p < 0.01$) between the fat content and color values (Table 2). The fat content of sucuks had significant positive correlation coefficients with the L^* ($r = 0.569$, $p < 0.01$)

Table 2. Pearson linear correlation analysis results (correlation coefficients, *r*) of the physicochemical characteristics[1] of fermented camel sucuks.

	Moisture	Fat	Protein	Ash	CH	Energy	Salt	pH	aw	*L**	*a**	*b**	*C*	*°H*	CS	TBARS
Moisture	1.000															
Fat	0.712**	1.000														
Protein	0.385**	0.345**	1.000													
Ash	-0.172	0.025	0.190	1.000												
CH	0.176	0.163	0.307**	0.137	1.000											
Energy	0.904**	0.937**	0.017	0.099	0.003	1.000										
Salt	0.359**	0.213	0.151	0.753**	0.212	0.291**	1.000									
pH	0.742**	0.527**	0.286*	-0.291*	0.215	0.677**	0.449**	1.000								
aw	0.635**	0.421**	0.258*	-0.323**	0.279*	0.562**	0.458**	0.661**	1.000							
*L**	-0.259*	0.569**	-0.378**	0.059	-0.089	0.457**	0.103	0.313**	-0.256*	1.000						
*a**	0.542**	0.544**	0.020	-0.167	-0.062	0.596**	0.282*	0.557**	0.439**	-0.330**	1.000					
*b**	0.410**	0.385**	0.045	-0.159	0.116	0.432**	0.307**	0.299**	0.319**	-0.161	0.505**	1.000				
C	0.637**	0.625**	0.046	-0.167	-0.065	0.687**	0.310**	0.570**	0.474**	-0.327**	0.903**	0.763**	1.000			
H	0.128	0.189	0.070	-0.025	0.033	0.172	-0.039	-0.227*	0.111	0.171	0.463**	0.403**	0.225*	1.000		
CS	0.518**	0.632**	0.109	0.086	0.035	0.639**	-0.053	0.449**	0.372**	0.451**	0.338**	0.324**	0.470**	0.096	1.000	
TBARS	0.450**	0.665**	0.250*	0.022	0.111	0.620**	0.103	-0.343**	0.375**	0.393**	0.629**	0.350**	0.638**	0.313**	0.470**	1.000

[1]CH: Carbohydrate; *L**: Lightness; *a**: redness; *b**: yellowness; *C*: chroma; *°H*: hue angle; a_w: water activity; CS: Cholesterol. *P < 0.05; **P < 0.01.

values. Conversely, negative correlation coefficients were found between fat content and *a** (*r* = –0.544, p <0.01), *b** (*r* = –0.385, p <0.01) and chroma (*r* = –0.625, p <0.01) values. Lorenzo et al. (2017) reported that *L** values increased and *a** values decreased with increasing fat content in sausages. In this study, *L** values were moderately correlated with TBARS (*r* = 0.393, p <0.01), protein contents (*r* = –0.378, p <0.01) and pH (*r* = –0.313, p <0.01). In addition, *L** values were weakly negatively correlated with moisture contents (*r* = –0.259, p <0.05). Lorenzo et al. (2017) observed that there was the same relationship between *L** and protein values as those found in this study. The *a** values were significantly correlated with TBARS (*r* = –0.629, p <0.01), moisture contents (*r* = 0.542, p <0.01) and pH (*r* = 0.557, p <0.01). Meanwhile, TBARS had significant correlations (p <0.01) with *b** (*r* = -0.350), chroma (*r* = –0.638), and hue angle (*r* = 0.313) values. The pH values had a weak correlation with *b** (*r* = 0.299, p <0.01) and hue angle (*r* = –0.227, p <0.05), and a moderate correlation (p <0.01) with chroma (0.570) values. In addition, Hernández-Hernández et al. (2009) reported a similarly negative correlation between TBARS and chroma values (*r* = –0.922). The authors also stated that myoglobin and oxymyoglobin oxidation caused higher hue angle and lower chroma values.

3.2 Chemical composition, energy, cholesterol and TBARS results

The average values (within the range) of the chemical composition (Table 3) were 40.07% ± 3.87 (31.09% to 46.80%) for moisture, 21.11% ± 2.65 (17.49% to 27.74%) for protein, 34.02% ± 3.65 (27.40% to 41.39%) for fat, 4.05% ± 0.32 (3.41% to 4.56%) for ash, 0.88% ± 0.50 (0.35% to 2.15%) for carbohydrate and 3.32% ± 0.35 (2.71% to 3.76%) for salt. These moisture and fat results are in agreement with those reported by Mejri et al. (2017) and Kök et al. (2006). On the other hand, higher moisture and lower fat values were determined in the research results reported by Kargozari et al. (2014). The protein contents obtained in this research were similar to the results (in the range of 15.75 to 27.78%) of previous studies on camel sausages (El Adab et al., 2020; Mejri et al., 2017). In addition, it was observed that the protein contents found in all of the sucuks examined were higher than the lower limit value (16%) reported by the Turkish Food Codex (Turkey, 2012). The average ash content determined in this study was similar to the results (3.99%) found by Kök et al. (2006). On the other hand, this average ash content was lower than the result reported by Kargozari et al. (2014) (5.17%). In contrast, Ambrosiadis et al. (2004) observed a lower average ash value (2.99%) in traditional Greek sausages. Kök et al. (2006) found that the salt contents in fermented sausages ranged from 2.36% to 4.50%. There is a great variation in terms of salt content among fermented sausages according to the results obtained in present and previous studies. These differences may be explained by the different sausage formulations and final moisture contents.

Table 3. Chemical composition (%) results of fermented camel sucuks (n=40).

	Mean ± SD[1]	Minimum	Maximum
Moisture (%)	40.07 ± 3.87	31.09	46.80
Protein (%)	21.11 ± 2.65	17.49	27.74
Fat (%)	34.02 ± 3.65	27.40	41.39
Ash (%)	4.05 ± 0.32	3.41	4.56
Salt (%)	3.32 ± 0.35	2.71	3.76
Carbohydrate (%)	0.88 ± 0.50	0.35	2.15
Moisture/protein ratio	2.31 ± 0.29	1.39	2.55
Fat/protein ratio	1.52 ± 0.29	1.15	2.32
Energy (kcal/100 g)	394.14 ± 30.66	338.58	465.29
Cholesterol (mg/100 g)	76.22 ± 12.49	56.16	96.40
TBARS (mg MDA/kg)	0.72 ± 0.29	0.33	1.55

[1]SD: Standard deviation.

The Pearson's correlation analysis showed that moisture contents (Table 2) were highly related (p <0.01) to fat contents (-0.712), and moderately related (p <0.01) to protein contents (-0.385). In addition, there was a moderately significant negative correlation between fat contents and protein contents (*r* = –0.345,

p <0.01). Ash content was significantly positively correlated to salt content (r = 0.753, p <0.01). Furthermore, there was a moderately negative correlation between salt and moisture content (r = –0.359, p <0.01). Similarly, some studies reported that the moisture contents decreased with increased fat content in sausages (Ambrosiadis et al., 2004; Lorenzo et al., 2017).

The average moisture/protein and fat/protein ratios (within the range) of camel sucuks (Table 3) were 2.31 ± 0.29 (1.39 to 2.55) and 1.52 ± 0.29 (1.15 to 2.32), respectively. According to the Turkish Food Codex (Turkey, 2012), the moisture/protein and fat/protein ratios are required to be lower than 2.5 for fermented sucuks. In this study, the moisture/protein (except for one sample) and the fat/protein ratios of all sucuks complied with the limit value specified by the Turkish Food Codex (Turkey, 2012). Similarly, Papadima et al. (1999) found an average moisture/protein ratio of 2.29 for traditional Greek sausages. Moreover, a lower moisture/protein ratio was found in this study with respect to the results reported by Ambrosiadis et al. (2004).

The energy values (Table 3) of fermented camel sucuks ranged from 338.58 kcal/100 g to 465.29 kcal/100 g whereas the average energy value was 394.14 kcal/100 g (± 30.66). Ruiz-Capillas et al. (2012) and García et al. (2002) reported similar energy values in fermented sausages. The main determining factor of the differences in the energy values of sucuks is their fat content (Ruiz-Capillas et al., 2012). This situation was also revealed by the Pearson's correlation analysis (Table 2). Accordingly, there was a strong positive correlation between energy values and fat contents (r = 0.937, p <0.01). In addition, energy values showed a good negative correlation coefficient with moisture contents (r = –0.904, p <0.01). These results are in agreement with the findings of García et al. (2002), who reported that the energy values of fermented sausages decreased with decreasing fat contents.

Cholesterol and TBARS levels (Table 3) of camel sucuks were in the range from 56.16 to 96.4 mg/100 g and from 0.33 to 1.55 mg MDA/kg, respectively. Similar cholesterol levels (66.3 mg/100 g to 97.0 mg/100 g) in fermented sausages were reported by Zanardi et al. (2004). With respect to the TBARS levels, it was observed there were similar changes in TBA levels (0.26 mg MDA/kg to 1.54 mg MDA/kg) in fermented sausages during the ripening periods in the study conducted by Baka et al. (2011). TBARS is a major quality index of lipid oxidation, measuring secondary oxidation products. Gómez et al. (2015) stated that the acceptable upper TBARS limit value for rancidity is 2 mg MDA/kg. In this study, TBARS levels of all sucuks were lower than this acceptable threshold value.

According to the Pearson's correlation analysis (Table 2), fat contents were moderately positively related to cholesterol (r = 0.632, p <0.01) and TBARS levels (r = 0.665, p <0.01). These correlation results found between fat and TBARS levels were similar to those found by Ahmad & Srivastava (2007).

3.3 Microbiological characteristics and hygienic status

The results of the microbiological analysis (Table 4) demonstrated that the average (within its range) of microbial counts (log CFU/g) obtained from camel sucuks for APC, yeasts and molds, coliform bacteria, *Lactobacillus* spp. and *Streptococcus-Lactococcus* spp. were 6.58 ± 0.96 (4.51 to 8.31), 3.29 ± 0.64 (2.30 to 4.67), 3.10 ± 0.87 (<1.00 to 5.37), 4.15 ± 0.95 (2.32 to 6.62) and 4.74 ± 1.03 (2.47 to 6.30), respectively. Likewise, Drosinos et al. (2005) reported that the APC counts of naturally fermented sausages were in a range from 4.33 Log CFU/g to 8.77 log CFU/g. Similar results for APC in traditionally fermented sausages were also reported by Kozačinski et al. (2008). Meantime, Papadima et al. (1999) and Comi et al. (2005) reported higher APC levels in naturally fermented sausages. Additionally, APC counts in this study were higher than the levels of 1.4×10^4 to 2.9×10^6 CFU/g determined by Kök et al. (2006). These differences in APC results obtained in present and previous studies might be a consequence of the different fermentation time and conditions, initial microbial loads, storage conditions and hygienic quality observed during the processing period.

Yeast and mold counts obtained in this study were in agreement with those determined by El Adab et al. (2020). In addition, Ahmad & Srivastava (2007) stated that counts of yeast and mold should exceed a level of 4 log CFU/g to cause for spoilage. The yeast and mold counts (Figure 1) of 7 (17.5%)

Table 4. Microbiological analysis results (Log CFU/g) of fermented camel sucuks (n=40).

Microorganism type	Positive samples/ Total samples	Mean ± SD[3]	Min[4]	Max
APC[1]	40/40	6.58 ± 0.96	4.51	8.31
Total coliform bacteria	29/40	3.10 ± 0.87	<1.00	5.37
Yeasts and molds	40/40	3.29 ± 0.64	2.30	4.67
Lactobacillus spp.	40/40	4.15 ± 0.95	2.32	6.62
Streptococcus-Lactococcus spp.	40/40	4.74 ± 1.03	2.47	6.30
Escherichia coli	0/40	<1.00	<1.00	<1.00
Bacillus cereus	24/40	3.22 ± 1.07	<1.00	5.76
Staphylococcus aureus	9/40	3.27 ± 0.81	<1.00	4.54
Salmonella spp.	0/40	N.D.[2]	N.D.	N.D.
Listeria monocytogenes	0/40	N.D.	N.D.	N.D.

[1]APC: Total aerobic plate count; [2]N.D.: Not detected; [3]SD: Standard deviation; [4]Min: Minimum; Max: Maximum. The mean values were calculated according to the number of positive samples.

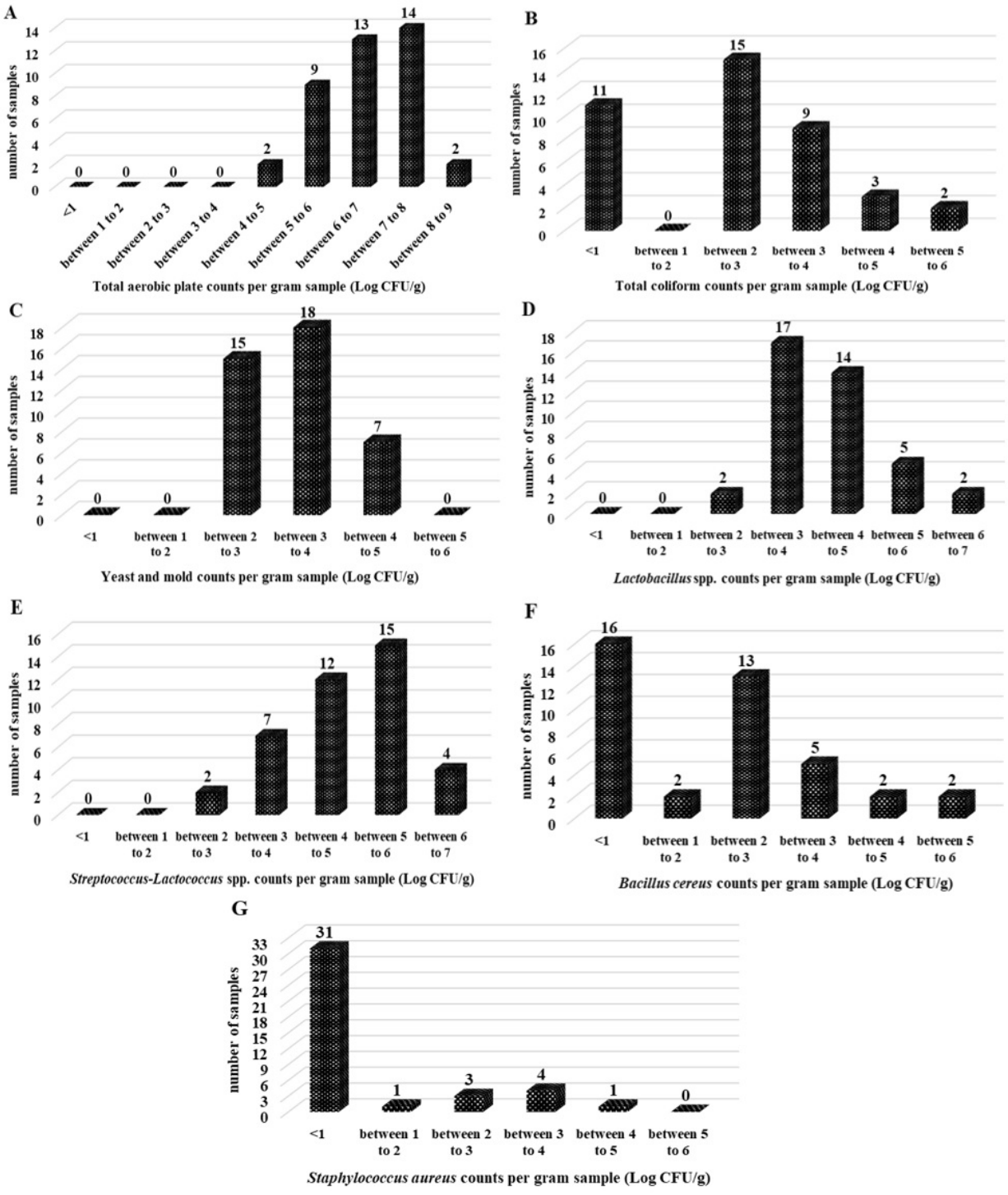

Figure 1. Quantitative results for the microbiological characteristics and hygienic status in the camel sucuks evaluated. (A) Contamination levels of total aerobic plate; (B) Contamination levels of total coliforms; (C) Contamination levels of yeasts and molds; (D) Contamination levels of *Lactobacillus* spp.; (E) Contamination levels of *Streptococcus-Lactococcus* spp.; (F) Contamination levels of *Bacillus cereus*; (G) Contamination levels of *Staphylococcus aureus*).

sucuks (4.14 to 4.67 log CFU/g) were determined to be slightly higher than the value stated by Ahmad & Srivastava (2007).

In the present study (Figure 1), total coliform bacteria count of 11 (27.5%) sucuks was below the detection limit (<1 log CFU/g). In order to perform statistical calculations, the coliform counts obtained below the detection limit were accepted equal to be zero. Coliform counts of 29 (72.5%) sucuks ranged from 2.19 log CFU/g to 5.37 Log CFU/g. A similar result for coliform counts was reported by Lizaso et al. (1999). On the

other hand, coliform counts determined in this study were lower than the counts of 4.85 log CFU/g to 6.72 Log CFU/g found by Casquete et al. (2012).

With respect to the counts of *Lactobacillus* spp. and *Streptococcus-Lactococcus* spp., Erkmen & Bozkurt (2004) reported the partly similar results in retailed sucuks. On the other hand, the lower lactic acid bacteria (LAB) counts were determined in this study according to the results found by Papadima et al. (1999) and Ambrosiadis et al. (2004). In contrast, Kök et al. (2006) found lower counts of LAB in fermented camel sausages.

The counts of *Escherichia coli*, *B. cereus* and *Stapylococcus aureus* were made to determine the hygienic status of camel sucuks. In addition, the presence of *Salmonella* spp. and *Listeria monocytogenes* were investigated to reveal their hygienic status. *E. coli* is the most important foodborne pathogenic bacteria transmitted by fecal or oral route, and its presence in foods is the result of insufficient hygienic conditions in processing area. Thus, *E. coli* is considered as an indicator bacterium for fecal contamination in food safety and hygiene (Ekici & Dümen, 2019). The spores and vegetative forms of *B. cereus* are widely distributed in the environment namely soil, dust, air, water, decaying matter and plants. The most important sources for *B. cereus* contamination to the foods are processing equipment, raw materials, water and air (Tewari & Abdullah, 2015). *S. aureus* is a wide spread commensal and opportunistic pathogen found the skin and mucosa of humans and animals, with the rates of nasal carriage between 30% and 50% in the adult population (Gallina et al., 2013).

Counts of *E. coli* were below the detection limit (<1.00 log CFU/g) for all sucuks (Table 4). The upper limit of acceptability for *E. coli* counts is stated to be 5×10^2 CFU/g (Turkey, 2011). Considering this threshold value, it was seen that none of the *E. coli* counts for sucuks exceed the specified limit value. Furthermore, *E. coli* counts obtained in this study were similar to those obtained in some other investigations into fermented sausages (Comi et al., 2005; Ducic et al., 2016).

The *B. cereus* counts of sucuks ranged between <1.00 (detection limit) and 5.76 log CFU/g whereas the average *B. cereus* count was 3.22 ± 1.07 log CFU/g (Table 4). *B. cereus* counts in 16 (40%) out of the 40 sucuk samples were below the detection limit (1 log CFU/g; Figure 1), while *B. cereus* counts of 24 (60%) sucuks ranged between 1.78 log CFU/g and 5.76 log CFU/g. According to the Turkish Food Codex (Turkey, 2011), the upper limit of acceptability for *B. cereus* counts is 3 log CFU/g. The *B. cereus* counts of 9 (22.5%) sucuks (3.07 to 5.76 log CFU/g) were determined to exceed this upper limit value. The numbers of *B. cereus* required to ensure sufficient toxins production to potentially cause food poisoning are 5-8 log CFU/g for emetic types of disease and 4-9 log CFU/g for diarrheal syndrome (Tewari & Abdullah, 2015). Moreover, Yu et al. (2020) pointed out that *B. cereus* can cause food poisoning even at lower doses, therefore more than 10^3 CFU/g considered unsafe for consumption. Considering these values, it can be stated that the counts of *B. cereus* obtained from sucuk samples (3.07-5.76 log CFU/g) may pose a risk for public health.

The average *S. aureus* count for camel sucuks (Table 4) was 3.27±0.81 log CFU/g (<1.00 to 4.54). *S. aureus* counts of 31 (77.5%) sucuks were below the detection limit (1 log CFU/g). On the other hand, *S. aureus* counts of 9 (22.5%) sucuks ranged from 1.82 log CFU/g to 4.54 log CFU/g (Figure 1). The threshold value for the number of *S. aureus* that can be found in food products has been reported to be 3 log CFU/g (Turkey, 2011). *S. aureus* counts of 5 (12.5%) sucuk samples (3.17-4.54 log CFU/g) were detected to exceed this upper limit value (3 log CFU/g). On the other hand, Kadariya et al. (2014) noted that *S. aureus* enterotoxin does not normally reach levels that will cause food poisoning until the counts of the pathogen reach at least 10^5 CFU/g. Moreover, Hennekinne et al. (2012) reported that the temperature, pH and water activity values required for *S. aureus* to produce enterotoxin ranged between 10 to 45 °C, 4 to 9.6, 0.85 to 0.99, respectively. Considering to the conditions for enterotoxin production by *S. aureus*, it can be expressed that *S. aureus* counts of some sucuk samples may represent a risk for public health. Blaiotta et al. (2004) noted that *S. aureus* counts in 22 out of the 37 traditional fermented sausages ranged between 2.00 and 4.16 log CFU/g. The authors also reported that *S. aureus* counts in 15 fermented sausages were lower than the detection limit (<2.00 log CFU/g). Meanwhile, it was reported that *S. aureus* counts were determined below the detection limit (2 log CFU/g) in all naturally fermented sausages in the study conducted by Comi et al. (2005).

Salmonella spp. and *Listeria monocytogenes* were not detected in any sucuk samples (Table 4). All sucuks analyzed were in compliance with the Turkish Food Codex (Turkey, 2011) in terms of the presence of *Salmonella* spp. and *L. monocytogenes* in ready-to-eat food products. Similar results related to the presence of *Salmonella* spp. and *L. monocytogenes* are found in other investigations into traditionally fermented sausages (Comi et al., 2005; Drosinos et al., 2005; Kozačinski et al., 2008).

According to the Pearson's correlation analysis, pH values were significantly correlated with *Lactobacillus* spp. (r = -0.747, p <0.01), *Streptococcus-Lactococcus* spp. (r =–0.653, p <0.01), APC (r = –0.279, p <0.05), yeasts and molds (r = –0.302, p <0.01), coliforms (r = 0.672, p <0.01), *B. cereus* (r = 0.591, p <0.01) and *S. aureus* (r = 0.485, p <0.01). Likewise, Baka et al. (2011) reported that pH levels of fermented sausages decreased with increasing LAB counts during the processing period. A similarly positive correlation coefficient between pH and coliform counts was also reported in the study conducted by Koutsopoulos et al. (2008). The a_w values of sucuks had a significant negative correlation coefficient with *Lactobacillus* spp. (r = –0.603, p <0.01), *Streptococcus-Lactococcus* spp. (r = –0.505, p <0.01), APC (r = –0.378, p <0.01), and yeasts and molds (r = –0.315, p <0.01). On the other hand, positive correlation coefficients were found between a_w values and coliforms (r = 0.622, p <0.01), *B. cereus* (r = 0.499, p <0.01) and *S. aureus* (r = 0.415, p <0.01). Similarly, Roig-Sagués et al. (1999) noted that a significant positive correlation was found between the a_w and the growth of coliform and pathogenic bacteria. In this present study, total coliform counts of camel sucuks had significant negative correlation coefficients with *Lactobacillus* spp. (r = –0.515, p <0.01) and *Streptococcus-Lactococcus* spp. (r = –0.396, p <0.01) counts. In addition, there was a moderately negative correlation between the *Lactobacillus* spp. and *B. cereus*

counts (r = –0.421, p <0.01), and *Lactobacillus* spp. and *S. aureus* counts (r = –0.457, p <0.01). Ambrosiadis et al. (2004) reported that LAB, through the production of lactic acid, acetic acid and bacteriocins in traditional sausages, prevented the growth of pathogenic bacteria.

4 Conclusions

In this study, the physicochemical and microbiological characteristics and hygienic status of camel sucuks were evaluated. As a result, it was determined that the camel sucuks generally complied with the legal regulations in terms of physicochemical characteristics (except for the pH results). However, there was no standardization among products in terms of physicochemical characteristics. Microbiological characteristics were generally in compliance with the legal limits, but some sucuks exceeded the threshold values in terms of coliforms and yeasts-molds. In addition, the *E. coli* counts of all sucuks were below the detection limit. Whereas *B. cereus* was detected in 24 (60%) sucuks, it was observed that the counts for *B. cereus* in 9 (22.5%) sucuks exceeded the acceptable threshold value. *S. aureus* was detected in 9 (22.5%) sucuks. *S. aureus* counts in only 5 (12.5%) sucuks were found to exceed the acceptable threshold value. *Salmonella* spp. and *Listeria monocytogenes* were not detected in any sucuks. In conclusion, this research indicated that the hygienic quality of some fermented camel sucuks was insufficient. The current situation has the potential to pose a risk to consumer health. The contamination of these products with pathogenic bacteria may arise from various factors, such as raw materials, processing and storage conditions. In order to prevent these contaminations, hygienic processing techniques must be applied.

Conflict of interest

Author does not have any conflict of interests to disclose.

Acknowledgements

The author would like to thank to Prof. Dr. Birol Kılıç for his support about the use of laboratory facilities.

References

Ahmad, S., & Srivastava, P. K. (2007). Quality and shelf life evaluation of fermented sausages of buffalo meat with different levels of heart and fat. *Meat Science*, 75(4), 603-609. http://dx.doi.org/10.1016/j.meatsci.2006.09.008. PMid:22064024.

Ambrosiadis, J., Soultos, N., Abrahim, A., & Bloukas, J. G. (2004). Physicochemical, microbiological and sensory attributes for the characterization of Greek traditional sausages. *Meat Science*, 66(2), 279-287. http://dx.doi.org/10.1016/S0309-1740(03)00100-1. PMid:22064129.

Association of Official Analytical Chemists – AOAC. (1997). *Official methods of analysis* (15th ed.). Washington: AOAC.

Ayyash, M., Liu, S. Q., Al Mheiri, A., Aldhaheri, M., Raeisi, B., Al-Nabulsi, A., Osaili, T., & Olaimat, A. (2019). In vitro investigation of health-promoting benefits of fermented camel sausage by novel probiotic Lactobacillus plantarum: A comparative study with beef sausages. *Lebensmittel-Wissenschaft + Technologie*, 99, 346-354. http://dx.doi.org/10.1016/j.lwt.2018.09.084.

Baka, A. M., Papavergou, E. J., Pragalaki, T., Bloukas, J. G., & Kotzekidou, P. (2011). Effect of selected autochthonous starter cultures on processing and quality characteristics of Greek fermented sausages. *Lebensmittel-Wissenschaft + Technologie*, 44(1), 54-61. http://dx.doi.org/10.1016/j.lwt.2010.05.019.

Blaiotta, G., Pennacchia, C., Villani, F., Ricciardi, A., Tofalo, R., & Parente, E. (2004). Diversity and dynamics of communities of coagulase-negative staphylococci in traditional fermented sausages. *Journal of Applied Microbiology*, 97(2), 271-284. http://dx.doi.org/10.1111/j.1365-2672.2004.02298.x. PMid:15239693.

Casquete, R., Benito, M. J., Martín, A., Ruiz-Moyano, S., Aranda, E., & Córdoba, M. G. (2012). Microbiological quality of salchichón and chorizo, traditional Iberian dry-fermented sausages from two different industries, inoculated with autochthonous starter cultures. *Food Control*, 24(1-2), 191-198. http://dx.doi.org/10.1016/j.foodcont.2011.09.026.

Comi, G., Urso, R., Iacumin, L., Rantsiou, K., Cattaneo, P., Cantoni, C., & Cocolin, L. (2005). Characterisation of naturally fermented sausages produced in the North East of Italy. *Meat Science*, 69(3), 381-392. http://dx.doi.org/10.1016/j.meatsci.2004.08.007. PMid:22062975.

Drosinos, E. H., Mataragas, M., Xiraphi, N., Moschonas, G., Gaitis, F., & Metaxopoulos, J. (2005). Characterization of the microbial flora from a traditional Greek fermented sausage. *Meat Science*, 69(2), 307-317. http://dx.doi.org/10.1016/j.meatsci.2004.07.012. PMid:22062823.

Ducic, M., Klisara, N., Markov, S., Blagojevic, B., Vidakovic, A., & Buncic, S. (2016). The fate and pasteurization-based inactivation of *Escherichia coli* O157, *Salmonella* Typhimurium and *Listeria monocytogenes* in dry, fermented sausages. *Food Control*, 59, 400-406. http://dx.doi.org/10.1016/j.foodcont.2015.06.014.

Ekici, G., & Dümen, E. (2019). *Escherichia coli* and food safety. In M. S. Erjavec (Ed.), *The universe of Escherichia coli*. London: IntechOpen. http://dx.doi.org/10.5772/intechopen.82375.

El Adab, S., Wadda, W. B., Tekiki, A., Moussa, O. B., Boulares, M., Sadok, S., & Hassouna, M. (2020). Effect of mixed starter cultures on biogenic amine formation during the ripening of tunisian dry fermented camel meat sausage. *Italian Journal of Food Science*, 32(2), 321-336. http://dx.doi.org/10.14674/IJFS-1733.

Erkmen, O., & Bozkurt, H. (2004). Quality characteristics of retailed sucuk (Turkish dry-fermented sausage). *Food Technology and Biotechnology*, 42(1), 63-69.

Gallina, S., Bianchi, D. M., Bellio, A., Nogarol, C., Macori, G., Zaccaria, T., Biorci, F., Carraro, E., & Decastelli, L. (2013). Staphylococcal poisoning foodborne outbreak: epidemiological investigation and strain genotyping. *Journal of Food Protection*, 76(12), 2093-2098. http://dx.doi.org/10.4315/0362-028X.JFP-13-190. PMid:24290688.

García, M. L., Dominguez, R., Galvez, M. D., Casas, C., & Selgas, M. D. (2002). Utilization of cereal and fruit fibres in low fat dry fermented sausages. *Meat Science*, 60(3), 227-236. http://dx.doi.org/10.1016/S0309-1740(01)00125-5. PMid:22063393.

Gómez, I., Beriain, M. J., Mendizabal, J. A., Realini, C., & Purroy, A. (2015). Shelf life of ground beef enriched with omega-3 and/or conjugated linoleic acid and use of grape seed extract to inhibit lipid oxidation. *Food Science & Nutrition*, 4(1), 67-79. http://dx.doi.org/10.1002/fsn3.251. PMid:26788312.

Güven, K., Mutlu, M. B., & Avci, O. (2006). Incidence and characterization of *Bacillus cereus* in meat and meat products consumed in Turkey. *Journal of Food Safety*, 26(1), 30-40. http://dx.doi.org/10.1111/j.1745-4565.2005.00031.x.

Hennekinne, J. A., De Buyser, M. L., & Dragacci, S. (2012). *Staphylococcus aureus* and its food poisoning toxins: characterization and outbreak

investigation. *FEMS Microbiology Reviews*, 36(4), 815-836. http://dx.doi.org/10.1111/j.1574-6976.2011.00311.x. PMid:22091892.

Hernández-Hernández, E., Ponce-Alquicira, E., Jaramillo-Flores, M. E., & Guerrero Legarreta, I. (2009). Antioxidant effect rosemary (*Rosmarinus officinalis* L.) and oregano (*Origanum vulgare* L.) extracts on TBARS and colour of model raw pork batters. *Meat Science*, 81(2), 410-417. http://dx.doi.org/10.1016/j.meatsci.2008.09.004. PMid:22064182.

International Organization for Standardization – ISO. (2017a). *ISO 11290-1:2017: microbiology of the food chain-horizontal method for the detection and enumeration of Listeria monocytogenes and of Listeria spp. - part 1: detection method*. Geneva: ISO.

International Organization for Standardization – ISO. (2017b). *ISO 6579-1:2017: microbiology of the food chain-horizontal method for the detection, enumeration and serotyping of Salmonella – part 1: detection of Salmonella spp*. Geneva: ISO.

Kadariya, J., Smith, T. C., & Thapaliya, D. (2014). *Staphylococcus aureus* and staphylococcal food-borne disease: an ongoing challenge in public health. *BioMed Research International*, 2014, 827965. http://dx.doi.org/10.1155/2014/827965. PMid:24804250.

Kadim, I. T., Mahgoub, O., & Purchas, R. W. (2008). A review of the growth, and of the carcass and meat quality characteristics of the one-humped camel (*Camelus dromedaries*). *Meat Science*, 80(3), 555-569. http://dx.doi.org/10.1016/j.meatsci.2008.02.010. PMid:22063567.

Kargozari, M., Moini, S., Basti, A. A., Emam-Djomeh, Z., Ghasemlou, M., Martin, I. R., Gandomi, H., Carbonell-Barrachina, A. A., & Szumny, A. (2014). Development of Turkish dry-fermented sausage (sucuk) reformulated with camel meat and hump fat and evaluation of physicochemical, textural, fatty acid and volatile compound profiles during ripening. *Lebensmittel-Wissenschaft + Technologie*, 59(2), 849-858. http://dx.doi.org/10.1016/j.lwt.2014.05.033.

Kök, F., Öksüztepe, G., İlhak, O. İ., & Patır, B. (2006). Chemical and microbiological quality of fermented sausages made from camel meat. *Medycyna Weterynaryjna*, 62(8), 893-896.

Koutsopoulos, D. A., Koutsimanis, G. E., & Bloukas, J. G. (2008). Effect of carrageenan level and packaging during ripening on processing and quality characteristics of low-fat fermented sausages produced with olive oil. *Meat Science*, 79(1), 188-197. http://dx.doi.org/10.1016/j.meatsci.2007.08.016. PMid:22062612.

Kozačinski, L., Drosinos, E., Čaklovica, F., Cocolin, L., Gasparik-Reichardt, J., & Vesković, S. (2008). Investigation of microbial association of traditionally fermented sausages. *Food Technology and Biotechnology*, 46(1), 93-106.

Lizaso, G., Chasco, J., & Beriain, M. J. (1999). Microbiological and biochemical changes during ripening of salchichón, a Spanish dry cured sausage. *Food Microbiology*, 16(3), 219-228. http://dx.doi.org/10.1006/fmic.1998.0238.

Lorenzo, J. M., Franco, D., & Carballo, J. (2017). Fat content of dry-cured sausages and its effect on chemical, physical, textural and sensory properties. In N. Zdolec (Ed.), *Fermented meat products: health aspects* (Chap. 20, pp. 474-487). Boca Raton: CRC Press.

Maqsood, S., Manheem, K., Abushelaibi, A., & Kadim, I. T. (2016). Retardation of quality changes in camel meat sausages by phenolic compounds and phenolic extracts. *Animal Science Journal*, 87(11), 1433-1442. http://dx.doi.org/10.1111/asj.12607. PMid:26968389.

Mejri, L., Ziadi, A., El Adab, S., Boulares, M., Essid, I., & Hassouna, M. (2017). Effect of commercial starter cultures on physicochemical, microbiological and textural characteristics of a traditional dry fermented sausage reformulated with camel meat and hump fat. *Journal of Food Measurement and Characterization*, 11(2), 758-767. http://dx.doi.org/10.1007/s11694-016-9445-6.

Papadima, S. N., & Bloukas, J. G. (1999). Effect of fat level and storage conditions on quality characteristics of traditional Greek sausages. *Meat Science*, 51(2), 103-113. http://dx.doi.org/10.1016/S0309-1740(98)00103-X. PMid:22061693.

Papadima, S. N., Arvanitoyannis, I., Bloukas, J. G., & Fournitzis, G. C. (1999). Chemometric model for describing Greek traditional sausages. *Meat Science*, 51(3), 271-277. http://dx.doi.org/10.1016/S0309-1740(98)00137-5. PMid:22061862.

Rajkovic, A., Jovanovic, J., Monteiro, S., Decleer, M., Andjelkovic, M., Foubert, A., Beloglazova, N., Tsilla, V., Sas, B., Madder, A., De Saeger, S., & Uyttendaele, M. (2020). Detection of toxins involved in foodborne diseases caused by Gram-positive bacteria. *Comprehensive Reviews in Food Science and Food Safety*, 19(4), 1605-1657. http://dx.doi.org/10.1111/1541-4337.12571. PMid:33337102.

Roig-Sagués, A. X., Hernández-Herrero, M. M., López-Sabater, E. I., Rodriguez-Jerez, J. J., & Mora-Ventura, M. T. (1999). Microbiological events during the elaboration of" fuet", a Spanish ripened sausage Relationships between the development of histidine-and tyrosine-decarboxylase-containing bacteria and pH and water activity. *European Food Research and Technology*, 209(2), 108-112. http://dx.doi.org/10.1007/s002170050467.

Rudel, L. L., & Morris, M. D. (1973). Determination of cholesterol using o-phthalaldehyde. *Journal of Lipid Research*, 14(3), 364-366. http://dx.doi.org/10.1016/S0022-2275(20)36896-6. PMid:14580182.

Ruiz-Capillas, C., Triki, M., Herrero, A. M., Rodriguez-Salas, L., & Jiménez-Colmenero, F. (2012). Konjac gel as pork backfat replacer in dry fermented sausages: Processing and quality characteristics. *Meat Science*, 92(2), 144-150. http://dx.doi.org/10.1016/j.meatsci.2012.04.028. PMid:22608829.

Schakel, S. F., Buzzard, I. M., & Gebhardt, S. E. (1997). Procedures for estimating nutrient values for food composition databases. *Journal of Food Composition and Analysis*, 10(2), 102-114. http://dx.doi.org/10.1006/jfca.1997.0527.

Sørensen, G., & Jørgensen, S. S. (1996). A critical examination of some experimental variables in the 2-thiobarbituric acid (TBA) test for lipid oxidation in meat products. *Zeitschrift fur Lebensmittel-Untersuchung und -Forschung*, 202(3), 205-210. http://dx.doi.org/10.1007/BF01263541.

Tewari, A., & Abdullah, S. (2015). *Bacillus cereus* food poisoning: international and Indian perspective. *Journal of Food Science and Technology*, 52(5), 2500-2511. http://dx.doi.org/10.1007/s13197-014-1344-4. PMid:25892750.

Turkey. Turkish Food Codex – TFC. (2011, December 29). Legislation of microbiological criteria. *The Official Gazette*, No. 28157.

Turkey. Turkish Food Codex – TFC. (2012). Legislation on meat and meat products. *The Official Gazette*, No. 2012/74.

World Health Organization – WHO. (2015). *Food safety* (Fact Sheet, No. 399). Geneva. Retrieved from http://www.who.int/mediacentre/factsheets/fs399/en/

Yu, S., Yu, P., Wang, J., Li, C., Guo, H., Liu, C., Kong, L., Yu, L., Wu, S., Lei, T., Chen, M., Zeng, H., Pang, R., Zhang, Y., Wei, X., Zhang, J., Wu, Q., & Ding, Y. (2020). A study on prevalence and characterization of *Bacillus cereus* in ready-to-eat foods in China. *Frontiers in Microbiology*, 10, 3043. http://dx.doi.org/10.3389/fmicb.2019.03043. PMid:32010099.

Zanardi, E., Ghidini, S., Battaglia, A., & Chizzolini, R. (2004). Lipolysis and lipid oxidation in fermented sausages depending on different processing conditions and different antioxidants. *Meat Science*, 66(2), 415-423. http://dx.doi.org/10.1016/S0309-1740(03)00129-3. PMid:22064145.