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RESEARCH ARTICLE

Quality Features of Afyon Fermented Sausage (Sucuk) and Standards Compliance

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ABSTRACT

Sucuk is one the indispensable tastes of Turkish cuisine that is preferred by a wide range of consumers. Hence, it must be produced in accordance with standards. In this study, it is aimed to specify the physicochemical and microbiological characteristics of Afyon Sucuk and their suitability to Communiqué on Turkish Food Codex Meat and Meat Products, Turkish Food Codex Microbiological Criteria Regulation and TS 1070 Sucuk Standard. As a result of our research, it is detected that in terms of pH, protein and fat contents; 83.3%, 26.66% and 16.66% of samples are not in the limits that are specified in the Turkish Food Codex Notification of Meat and Meat Products. On the other hand, the ash and salt contents of samples are determined to be in the limits of Communiqué on Turkish Food Codex Meat and Meat Products. In terms of total aerobic mesophilic bacteria and total yeast/ mold counts, 60% of samples had higher values than the specified limits in TS 1070. Total coliform counts, *Staphylococcus aureus, Escherichia coli, Salmonella spp.* and *Listeria monocytogenes* counts were found to be in accordance with Turkish Food Codex Microbiological Criteria Regulation and TS 1070 (TSE Turkish Fermented Sausage Standard).

Keywords: Afyonkarahisar, fermented sausage, microbiology, pH, quality

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Afyon Sucuğunun Kalite Özellikleri ve Standartlara Uygunluğu

ÖZ

Sucuk, Türk mutfağının vazgeçilmez lezzetlerinden biridir ve geniş bir tüketici kitlesi tarafından tercih edilmektedir. Bu nedenle, sucuğun kalite standartlarına uygun olarak üretilmesi önemlidir. Bu çalışmada Türkiye'de önemli bir yere ve pazara sahip olan Afyon sucuğunun fizikokimyasal ve mikrobiyolojik kalite kriterlerinin belirlenerek, Türk Gıda Kodeksi Et ve Et Ürünleri Tebliği, Türk Gıda Kodeksi Mikrobiyolojik Kriterler Yönetmeliği ve TS 1070 Sucuk Standardına uygunluğunun araştırılması amaçlanmıştır. Araştırma sonucunda örneklerimizin pH değeri bakımından, %83.3'ünün, protein değeri bakımından %26.66'sının, yağ değeri bakımından %16.66'sının Türk Gıda Kodeksi Et ve Et Ürünleri Tebliğinde belirtilen sınırlar dahilinde olmadığı belirlenmiştir. Ek olarak tüm örneklerimizin kül ve tuz miktarları bakımından Türk Gıda Kodeksi Et ve Et Ürünleri Tebliğinde belirtilen sınırlar içerisinde tespit edilmiştir. Ayrıca örneklerimizin toplam aerobik mezofilik bakteri ve toplam maya/küf sayıları bakımından %60'ının, TS 1070 sucuk standardında belirtilen sınırlardan daha yüksek olduğu, Toplam koliform grup bakteri sayısı, *Staphylococcus aureus, Escherichia coli, Salmonella spp.* ve *Listeria monocytogenes* türü bakteri sayılarının ise Türk Gıda Kodeksi Mikrobiyolojik Kriterler Yönetmeliği ve TS 1070 Sucuk Standardına uygun olduğu ortaya konulmuştur.

Anahtar kelimeler: Afyonkarahisar, fermente sosis, mikrobiyoloji, kalite, pH

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INTRODUCTION

Sucuk is a popular semi-dry fermented meat product that is mainly produced with the mixture of beef, buffalo, beef fat, sheep lard, salt, nitrate/ nitrite and various seasonings (Gökalp et al. 1997). Sucuk is a traditional delicious taste of Turkish cuisine that is preferred by a wide range of consumers. Production of sucuk must be in accordance with standards with regards to public health and product quality. Therefore, the investigation of the manufacturing process of sucuk and evaluation of quality features are crucial (Kılıç 2009).

In spite of the manufacturing nearly in every region of Turkiye, Afyon and Kayseri are the prominent cities in sucuk production (Artam 2018). Camel meat, buffalo meat, sheep and goat meats are also used in sucuk production in Turkiye other than beef. Rather than primary cuts, low-value cuts are commonly preferred in sucuk production (Sönmez 1986).

The lineament of Afyon sucuk is the use of significant proportions of buffalo meat in addition to beef in sucuk formulation. Afyon sucuk contains less spice and its taste is more pronounced. The unique flavour of Afyon sucuk results from the meat of buffalos that are grown in that region. Mentioned buffalos fed with aromatic plants as well as poppy seed meal. Hence, Afyon sucuk does not dry out easily while cooking and its ingestion is more efficient. As a consequence of its own undisturbing odor, it does not cause any indigestion (Artam 2018).

Afyonkarahisar region is one of the most important sucuk production centers in Turkiye and sucuks that have manufactured in this region have a large market share. Nevertheless, there are not many research about sucuk production in Afyonkarahisar region and its adherence to quality standards.

In this study, it is aimed to investigate the physicochemical and microbiological quality criteria and their compliance with Communiqué on Turkish Food Codex Meat and Meat Products, Turkish Food Codex Microbiological Criteria Regulation and TS 1070 Sucuk Standard.

MATERIAL and METHOD

Material

30 sucuk samples purchased from 30 different sucuk processing plants that have operating permits taken from the Ministry of Agriculture and Forestry according to Communiqué on Turkish Food Codex Meat and Meat Products (Communiqué No. 2012/74 and Communiqué No. 2015/7) within the scope of this study.

This study was carried out in two recidivisms, considering the two different production dates of the samples that were purchased from sales points. These samples were transported to the laboratory in sealed polyethylene bags within a cold chain and then stored at refrigeration temperatures until the analysis was completed.

Methods

Physicochemical analysis

pH value is one of the most important parameters that directly influences water holding capacity and shelf life of fermented meat products (Çiçek and Polat 2016). pH measurements were performed by a pHmeter (Ohaus, starter 3100) that was previously calibrated with pH 4.0 and 7.0 solutions (Gökalp et al 2001).

Dry matter contents of samples were determined according to AOAC 990.20 (AOAC 2016).

Samples were incinerated in a muffle furnace (Elektromag M 1811) at about 550 °C for 6-8 h and then cooled in a desiccator and weighed (AOAC 2016).

Fat contents were determined with Soxhelet apparatus using hexane as solvent (Ertaş et al. 2019).

Kjeldahl method was used to determine protein contents. Calculated nitrogen contents were multiplied by 6,25 to obtain protein contents (%) (Özyurt 2018).

Water activity values were determined by using Novasina LabTouch-aw (Lachen, Switzerland) (AOAC 2016).

Salt Content analysis

The salt contents of samples were determined according to the Mohr titration. 5 gr of the sample was solved with 50 ml distilled water. 0,5 ml of 5 % solution of potassium chromate indicator was added to each mixture and then titrated with standardized silver nitrate solution until a red-brown color persisted for 30 sec (Yalçın and Şeker 2016).

Color Measurements

Color measurements were performed by using a Konica Minolta Chroma Meter CR-400 (Japan) according to Hunter-Lab Color System. Mean values obtained from 5 measurements from inner, outer and lateral surfaces of sucuk samples in terms of lightness (L*), redness (a*) and yellowness (b*) according to the standard conditions of the Commission International d'Eclairage (CIE).

Also;

Hue angle: Ho = tan -1(b*/a*)

Saturation Index (Chroma): C* = (a*)2+(b*)2)1/2

Browning Index: BI = ((100* (x-0.31)) /0.17) values were calculated using L*, a* and b* (Kurtuldu and Özcan 2018).

Texture analysis

Texture Profile Analysis

TPA values were measured by TA.HD Plus Texture Analyser (Stable Micro Systems, Surrey, YL, England) at room temperature using 5 cm3 meat cubes. The

measurements were done with the following testing procedure: constant speed of 1mm/ s (pre-test), 5 mm/s (test) and 5 mm/s (post-test). A cylindrical 50 mm-diameter probe was used at a 20% compression rate (De Huidobro et al 2005).

Warner-Bratzler Shear Force

Shear force analysis of sucuk samples was performed with TA.HD Plus Texture Analyser (Stable Micro Systems, Surrey, YL, England). Square sections taken from samples were analysed using a WB shear blade probe (Ceylan 2022).

Microbiological Analysis

Microbiological analyses were performed with the spread plate method. 10 g of sample diluted in 90 ml Ringer's solution (Merck, 11525, Germany) and homogenized in a stomacher (Lab Stomacher Blender 400-BA 7021, Seward Medical). Dilution series were prepared by taking 1 mL from this homogenate. All spreading procedures were performed in double parallel runs and results are given in log CFU/g (Sekin and Karagözlü 2004).

The total mesophilic aerobic bacteria number was determined using Plate Count Agar (PCA) (Merck 1.05463, Germany). Inoculated plates were incubated at 30°C for 48-72 h (ISO 2008, ISO 2013). Man Rogasa and Sharpe Agar (MRS) (Merck 1.10661) was used to determine LAB counts, followed by incubation at 30°C for 24-48 h in an anaerobic jar (Merck 1.16387) (Kneifel 1994).

Yeast and mold counts were performed using Rose Bengal Chloramphenicol Agar (Merck 1.00467, Germany) (RBC). Inoculated petri dishes were incubated at 22°C for 5-7 days aerobically (ISO, 2013b). Total coliform counts were determined with Violet Red Bile Agar (Merck 1.01406, Germany) incubating aerobically at 30°C for 24 to 48 h (ISO 2015).

For *Staphylococcus aureus*, Baird Parker Agar (Merck 1.05406, Germany) and for *E. coli*, Chromocult TBX Agar (Merck 1.16122, Germany) were used. The plates were incubated aerobically at 30-35°C and 37°C for 24-48 h, respectively. At the end of incubation period, suspected colonies (black colonies with white margins) were picked and inoculated onto Baird Parker Agar once again with the same incubation conditions.

The growing colonies were subjected to a coagulase test (Bactident Coagulase, Merck 1.13306, Germany) and the positive ones were confirmed as *S. aureus*. For *E.coli* confirmation, the growing colonies were examined under UV light (366 nm) (ISO 1999, ISO 2001).

Salmonella spp. counts were determined by spread plates using Nutrient Broth (NB) (Merck 1.05443, Germany) Rappaport Vassiliadis Salmonella Enrichment Broth (RVS) (Merck 1.07700, Germany) and Brilliant Green Phenol Red Lactose Sucrose Agar (BPLS) (Merck 1.10747, Germany) and Xylose Lysine Deoxycholate Agar (XLD) (Merck 1.105287, Germany). Inoculated petri dishes were incubated aerobically at 37°C for 24-48 h (Greenwood et al. 1984, Flowers et al. 1992, ISO 2017).

Listeria monocytogenes counts were determined by plating on Fraser broth (Merck 1.10398, Germany) and Oxford Agar (Merck 1.07004, Germany) then incubation at 37°C for 24-48 h (ISO 2017).

Statistical Analysis

The study's results were achieved by performing two replicates and all analyses were done in two repetitions. The SPSS program version V 23.0.0 was used for the variance analysis. The significant levels of difference were determined using Duncan's multiple-range tests ($P<0.05$).

RESULTS

Physicochemical Analyses

pH values of sucuk samples are shown in Table 1. pH values ranged from 4.61 to 6.82 ($P<0.05$). The mean pH value is determined to be 6.21.

Table 1 shows the mean dry matter contents of 30 sucuk samples purchased from the sales points of the sucuk production plants with operating permits taken from the Ministry of Agriculture and Forestry. Dry matter values range between 41.83% and 69.11% ($P<0.05$). The mean dry matter content is determined to be 55.013%.

Ash contents of samples vary from 2.53 to 4.11%. The mean ash value is determined to be 3.22 %. ($P<0.05$; Table 1). About 13 samples (43.33%) are involved in the highest ash content range that varied from 3.0 to 3.5%. Only one sample (3.33%) was detected to be in the lowest ash content range that is in the >4.5%. None of the samples are detected to be in the <2.5%range.

Water activity values of samples vary between the range of 0.458-0.907 with a mean value of 0.785 ($P<0.05$; Table 1). About 13 samples (43.33 %) are involved in the highest ash content range that vary from 3.0 to 3.5%. Only one sample (3.33%) was detected to be in the lowest ash content range that is in the >4.5%. None of the samples were detected to be in the <2.5% range. According to Table 1, the highest aw value range consists of 12 samples (40%) between 0.800 to 0.900 whereas the lowest aw value with only 1 sample (3.33%) stands in the <0.500 range.

Minimum, maximum and mean fat contents of sucuk samples are determined to be 10.87%, 44.01% and 29.37%, respectively ($P<0.05$; Table 2).

The minimum, maximum and mean protein contents of 30 samples are as follows; 8.31%, 19.42% and 14.99%, respectively ($P<0.05$; Table 2).

Table 1. Number of sucuk samples and percentages in terms of physicochemical analysis and, pH, dry matter and ash contents

pH	Sample		Dry Matter (%)	Sample		Ash Content (%)	Sample		a_w	Sample	
	Number	%		Number	%		Number	%		Number	%
>6.0	23	76.66	>60	2	6.66	>4.0	1	3.33	>0.900	5	16.66
5.4-6.0	2	6.66	55-60	14	46.66	3.8-4.0	2	6.66	0.800-0.900	12	40
5.0-5.4	3	10	50-55	9	30	3.5-3.8	5	16.66	0.700-0.800	8	26.66
4.7-5.0	2	6.66	45-50	4	13.33	3.0-3.5	13	43.33	0.600-0.700	4	13.36
4.5-4.7	-	-	40-45	1	3.33	2.5-3.0	9	30	0.500-0.600	-	-
<4.5	-	-	<40	-	-	<2.5	-	-	<0.500	1	3.33
Minimum	4.61		Minimum	41.83		Minimum	2.53		Minimum	0.458	0.458
Maximum	6.82		Maximum	69.11		Maximum	4.411		Maximum	0.907	0.907
Mean	6.21±0.53		Mean	55.013±5.13		Mean	3.22±0.39		Mean	0.785 ±0.1 10	0.785± 0.110

Table 2. Number of sucuk samples and percentages in terms of physicochemical analysis and fat, protein and salt contents (n=30).

Fat content (%)	Sample		Protein (%)	Sample		Salt Content (%)	Sample	
	Number	%		Number	%		Number	%
>40	3	10	>19	2	6.66	>3,5	1	3.33
35-40	4	13.36	18-19	2	6.66	3.0-3.5	4	13.36
30-35	4	13.36	17-18	-	-	2.5-3.0	11	36.66
25-30	12	40	16-17	3	10	2.0-2.5	14	46.66
20-25	5	16.66	15-16	9	30	1.5-2.0	-	-
<20	2	6.66	<15	14	46.66	<1.5	-	-
Minimum	10.87		Minimum	41.83		Minimum	2.22	
Maximum	44.01		Maximum	69.11		Maximum	3.55	
Mean	29.37±7.20		Mean	55.013±5.13		Mean	2.64±0.32	

Salt Content

Salt contents of sucuk samples are shown in Table 2. Minimum, maximum and mean salt contents of the samples are detected to be as 2.2%, 3.55% and 2.64%, respectively.

Color Values

L* values of 30 samples are shown in Table 3. Maximum, minimum and mean L* values are; 55.83, 42,85 and 48.98, respectively ($P<0.05$). Hue angle values of sucuk samples are ranged between 25.77 and 53.14 ($P<0.05$) while chroma values are determined to be between 25.47 and 37.43 ($P<0.05$) as shown in Table 4. Minimum, maximum and mean whiteness index values of samples are determined to be 725.75, 1182.33 and 937.50, respectively ($P<0.05$).

Table 3. Number of sucuk samples and percentages in terms of physicochemical analysis and Color values (n=30).

L* Values	Sample		a* Values	Sample		b* Values	Sample	
	Number	%		Number	%		Number	**%**
>55	1	3.33	>30	1	3.33	>25	3	10
50-55	8	26.66	25-30	20	66.66	20-25	9	30
45-50	17	56.66	20-25	8	26.66	15-20	16	53.33
40-45	4	13.36	15-20	1	3.33	10-15	2	6.66
35-40	-	-	10-15	-	-	5-10	-	-
<35	-	-	<10	-	-	<5	-	-
Minimum	42.85		Minimum	15.28		Minimum	13.22	
Maximum	55.83		Maximum	30.32		Maximum	25.89	
Mean	48.98±3.09		Mean	25.49±2.76		Mean	19.07±3.14	

Table 4. Number of sucuk samples and percentages in terms of physicochemical analysis and Color values (n=30) (Continued).

Hue Angle	Sample		Chroma values	Sample		WI	Sample	
	Number	%		Number	%		Number	%
>45	2	6.66	>34	5	16.66	>1100	2	6.66
45-40	8	26.66	34-33	6	20	1050-1100	3	10
35-40	8	26.66	32-33	2	6.66	1000-1050	4	13.36
30-35	9	30	31-32	6	20	950-1000	5	16.66
25-30	3	10	30-31	7	23.33	900-950	10	3.33
<25	-	-	<30	4	13.36	<900	6	20
Minimum	25.77		Minimum	25.47		Minimum	725.75	
Maximum	53.14		Maximum	37.43		Maximum	1182.33	
Mean	36,80±5.93		Mean	31.99±2.65		Mean	937.50±2.65	

Textural analysis

Texture Profile Analysis and Warner-Bratzler Shear Force

The mean textural properties of 30 sucuk samples are as follows; hardness; 5933.86 N, adhesiveness;-88.31, springiness; 0.727 mm, cohesiveness; 0.575, gumminess; 3440.723N, chewiness; 2495.546 N and resilience; 0.18 (Table 5).

Maximum, minimum and mean Warner-Bratzler shear forces are determined to be 8201.02 kgf, 88.43 kgf and 145.30 kgf, respectively.

Microbiological Analysis

Total Aerobic Mesophilic Bacteria Counts

Total Aerobic Mesophilic Bacteria Counts of sucuk samples are determined to be as; minimum; <1 log cfu/g, maximum; 2.93 log cfu/g and mean 1.90 cfu/g ($P<0.05$; Table 6).

Lactic Acid Bacteria (LAB) Counts

LAB counts of 30 sucuk samples are determined to be in the range of 1.85 to 7.63 log cfu/g, with a mean of 6.21 log cfu/g ($P<0.05$; Table 6).

Total Yeast and Mold Counts (TYM)

Total mold and Yeast counts are determined to be in the 0.70- 4.65 log cfu/g range, with an average of 2.46 log cfu/g ($P<0.05$; Table 6).

Total Coliform Bacteria Counts

Total Coliform Count (TCC) of samples were ranged between <1 log cfu/g and 1.95 log cfu/g ($P<0.05$; Table 6).

***Staphylococcus aureus* counts**

S. aureus counts of sucuk samples were ranged between <1.0 log cfu/g- 2.07 log cfu/g with a mean count of 0.53 log cfu/g ($P<0.05$; Table 6).

Table 5. Number of sucuk samples and percentages in terms of textural properties and texture analysis results (n=30).

Hardness (N)	Sample		Adhesiveness	Sample		Springiness (mm)	Sample		Cohesiveness	Sample	
	Number	%		Number	%		Number	%		Number	%
>8500	2	6.66	>-50	4	13.36	>900	1	3.33	>0.700	3	10
7500-8500	6	20	-100 - -50	17	56.66	900-800	9	30	0.700-0.600	10	33.33
6500-7500	4	13.36	-150 - -100	4	13.36	800-700	10	33.33	0.600-0.500	10	33.33
5500-6500	5	16.66	-200 - -150	3	10	700-600	7	23.33	0.500-0.400	6	20
4500-5500	5	16.66	-250 - -200	2	6.66	600-500	3	10	0.400-0.300	1	3.33
<4500	8	26.66	<-250	-		<500			<0.300	-	-
Minimum	3609.12		Minimum	-205.47		Minimum	0.566		Minimum	0.365	
Maximum	8633.41		Maximum	-33.25		Maximum	0.909		Maximum	0.715	
Mean	5933.86±1657.84		Mean	-88.31±47.46		Mean	0.727±0.10		Mean	0.575±0.09	
Gumminess (N)	Sample		Chewiness (N)	Sample		Resilience	Sample		Warner-Bratzler Shear Force	Sample	
	Number	%		Number	%		Number	%		Number	%
>6000	2	6.66	>4000	2	6.66	>0.25	4	13.36	>180	5	16.66
5000-6000	2	6.66	3500-4000	3	10	0.20-0.25	7	23.33	160-180	6	20
4000-5000	5	16.66	3000-3500	3	10	0.15-0.20	8	26.66	140-160	7	23.33
3000-4000	8	26.66	2500-3000	4	13.66	0.10-0.15	9	30	120-140	3	10
2000-3000	10	33.33	2000-2500	8	26.66	0.10-0.05	2	6.66	100-120	6	20
<2000	2	6.66	<2500	10	33.33	<0.05	-	-	<100	3	10
Minimum	1731.356		Minimum	1238.396		Minimum	0.09		Minimum	88.43	
Maximum	6143.28		Maximum	5313.97		Maximum	0.28		Maximum	204.02	
Mean	3440.723±1221.267		Mean	2495.546±954.97		Mean	0.18±0.05		Mean	145.30±32.99	

Table 6. Number of sucuk samples and percentages in terms of microbiological properties and microbiological counts (n=30) (log cfu/g).

TAMB Count	Sample		LAB Count	Sample		Coliform Count	Sample		TYM Count	Sample		*S.aureus* Count	Sample	
	Number	%		Number	%		Number	%		Number	%		Number	%
>2.4	7	23.33	>7	16	53.3	>2	-	-	>3.0	9	30	>2	2	6.66
2.4-2.0	13	43.33	7.0-6.0	8	26.6	1.8-2.0	2	6.66	2.5-3.0	3	10	1.6-2.0	-	-
2.0-1.6	6	20	6.0-5.0	3	10	1.6-1.8	-	-	2.0-2.5	6	20	1.4-1.6	3	10
1.6-1.3	-	-	5.0-4.0	1	0.33	1.4-1.6	2	6.66	1.5-2.0	5	16.66	1.2-1.4	3	10
1.3-1	-	-	4.0-3.0	1	0.33	1.0-1.4	3	10	1.0-1.5	3	10	1.0-1.2	4	13.66
<1	4	13.66	<3.0	1	0.33	<1.0	23	76.6	<1.0	4	13.66	<1.0	18	60
Minimum	<1		Minimum	1.85		Minimum	<1.0		Minimum	0.70		Minimum	<1.0	
Maximum	2.93		Maximum	7.63		Maximum	1.95		Maximum	4.65		Maximum	2.07	
Mean	1.90±0.90		Mean	6.21±1.81		Mean	0.32±0.67		Mean	2.46±1.00		Mean	0.53±0.73	

DISCUSSIONS

Physicochemical Analyses

The ripening period of sucuk production consists of two main stages; fermentation and drying. During fermentation, Lactic acid bacteria metabolize glucose, the main energy source, to lactic acid. As a result, the pH declines, changing the texture and flavour (Bover-Cid 2001). Besides, water loss increases and the product dries out in a short time. Meanwhile, nitrite reduction occurs and desirable color and aroma formation accelerate and also the microbial deteriorations are inhibited (Gökalp et al. 1997). According to Communiqué on Turkish Food Codex Meat and Meat Products (Communiqué No. 2012/74) the maximum pH value of fermented sucuk should be 5,4 and it should be 5,6 for heat treated sucuk (Anonymous 2012). Consequently, 25 of the samples (about 83.3%) are above the stated limit in Communiqué on Turkish Food Codex Meat and Meat Products.

Following slaughter, the pH value of meat ranges between 7,1- 7,3; about 6 or 8 h later pH decreases to 5,6-5,7 as a result of rigor mortis. The high pH values of some sucuk samples are probably because of using meat that has not completed its Rigor mortis stage yet or DFD Meat (Dark Firm Dry) that has high water holding capacities. The use of excessive additives, particularly acid regulators, could be another factor.

Pehlivanoğlu et al. (2015) reported that the pH values of 12 of 30 sucuk samples (40%) that were supplied from İstanbul region were out of legal limits. They determined the minimum pH value as 4.21; the maximum pH value as 5.71 and the mean pH value was found to be 5.21. Similarly, Öksüztepe et al. determined the minimum, maximum and mean pH values of sucuk samples from Elazığ region were found to be 4.75, 6.76 and 5.18, respectively.

Current results are different from these previous studies. These differences may be on account of the different raw materials, differences on the type and amount of additives and also differences on production process, process conditions etc. Dry matter content in sucuk is one of the most important quality parameters that also affects consumer admirations.

According to the limit that set by Communiqué on Turkish Food Codex Meat and Meat Products, the ratio of moisture content to total meat protein must be less than 2,5; this ratio must be less than 3,6 in heat treated sucuk. One of 30 sucuk samples (3,33%) has the ratio above 3.6, whereas 27 of 30 samples (90%) have the ratio above 2.5. The high moisture content of samples may be a result of a short heat treatment followed by an insufficient drying process. These results are similar to those of others who also found dry matter contents in the range of 48.52% - 64.37% with a mean dry matter content of 56.72% (Özfiliz et al. 2018) and another study in the range of 33.09% - 74.03% with a mean value of 61.25% (Öksüztepe et al. 2011).

Weight loss due to moisture loss is one of the most significant losses in terms of product cost. Producers often use food additives with moisture retention properties and/or they marketize the products just before the whole production period. Our results are in the same line with these assumptions.

The formulation of sucuk, types and ratios of additives directly affect the ash contents of products. Additionally, the ultimate ash amounts are influenced significantly by the species, age and fattening type of animal, besides the muscles used in manufacture. Communiqué on Turkish Food Codex Meat and Meat Products does not contain any statements about ash limits. On the other hand, TS 1070 Sucuk Standard indicates that ash contents must be 2-5% for fermented sucuk. Ash contents of the current study conform with this regulation. Despite complying with the TS 1070 Sucuk Standard, these results are lower than previous findings by Erdoğrul and Ergün (2005), Sancak et al. (1996) and Öksüztepe et al. (2011) that indicated mean ash contents of sucuk samples as 5.20%, 3.99% and 5.39%, respectively.

Water activity has nearly the same value as pH in terms of a food's production and evaluation phases. This term expresses the amount of free water which is used for the metabolism and the proliferation of microorganisms in that food. Hence, it is supposed to be a stability indicator in terms of microbiological quality and it plays a significant role in food technology (Yıldırım 1996). Kara et al. (2021) reported aw values varying between 0.954-0.354 for sucuk samples. Differences with these similar studies may be on account of storage conditions and also properties of packaging materials.

The addition of fat is essential for sucuk production due to its ability to enhance the product's flavor and aroma as well as the desired marbling formation. Types, amount and storage conditions of these fats are critical factors from the standpoint of final consumption quality and also consumer acceptance. According to Communiqué on Turkish Food Codex Meat and Meat Products (Communiqué No. 2012/74) the ratio of fat content to total meat protein must be lower than 2,5 for both fermented and heat treated sucuk (Anonymous 2012). 5 samples (16.66%) fat contents were determined to be over this limit and the remaining samples were determined to be within the stated limit. According to TS 1070 Sucuk Standard, the maximum fat contents of I. Grade sucuk must be 35%; II. and III. Grades must be 40% (TS 2002). Therefore, 22 samples (73.33%) fat contents are lower than 35% and 7 (25.33%) samples fat contents are lower than 40%. One (3.33%)

remaining sample's fat content is determined to be more than 40 %. Consequently, 22 samples are confirmed to be I. Grade, 7 samples are confirmed to be II. and III. Grades. The remaining sample is out of this classification. Erdoğrul and Ergün (2005) reported the mean fat content of sucuk as 39,20%, Kolsarıcı et al. (1996) 37.15% and lastly Öksüztepe et al (2011) 35.22%. These values are much more than the present study's fat contents. This finding may be attributed to the alteration of limits in Communiqué on Turkish Food Codex Meat and Meat Products that came into effect in 2012. Producers have decreased the fat contents of sucuk formulations from the specified date according to legislation.

In terms of nutritional value as well as sucuk quality, protein is the most significant meat component. Similar previous studies reported the mean protein contents of sucuk samples as 22.48% (Erdoğrul and Ergün 2005) and 21.92% (Öksüztepe et al. 2011). Current results are partly lower than these previous values. These differences may be due to the differences in the breed, species and age of the animal, besides the used carcass cuts in the sucuk production. Another reason may be the updates in the formulations according to the alterations in Communiqué on Turkish Food Codex Meat and Meat Products.

Salt Contents

Salt content has quite important effects on the taste and aroma of sucuk. Besides enhancing taste, salt also improves the consistency properties of the product. Salt also inhibits microbial growth by reducing water activity (Şimşek et al. 2023). No legal maximum limits have been established for salt content by Communiqué on Turkish Food Codex Meat and Meat Products whereas a 5% maximum level has been set in TS 1070 Sucuk Standard (TS 2002). According to this standard, salt contents of all of the samples are within the established limits. Erdoğrul and Ergün (2005) reported the mean salt contents of sucuk samples in Kahramanmaraş province as 3.01 %. Öksüztepe et al (2011) reported minimum, maximum and mean salt contents of sucuk samples sold in Elazığ province as 1.63%, 6.41% and 4.36%, respectively. The added salt contents of the sucuk samples from different brands vary due to the lack of a legal limit in the regulations. Each brand determines its own salt content in the formulations depending on consumer demands.

Color Values

Color is an efficient factor that affects customer purchase tendency of meat products. The formation of color depends on curing agents, pigments and the reactions of other factors. Meat contains myoglobin, the most important one, hemoglobin, cytochrome flavin and some other color agents (Vural and Öztan 1992). Poçan et al. (2015) reported the L* values of fermented sucuks in the range of 44.91-55.20. Kara et al. (2021) determined the maximum, minimum and mean L* values of sucuk samples as 57.81, 31.34 and 47.80, respectively. Maximum, minimum and mean a* values of current samples were determined to be as 30.32, 15.28 and 25.49, respectively ($P<0.05$). Poçan et al. (2015) reported the a* values in the range of 19.40-25.95. In a similar study Kara et al. (2021) reported the maximum, minimum and mean a* values of sucuk samples as 29.02, 17.69 and 23.45, respectively. The maximum, minimum and mean b* values of our current samples were determined to be as 25.89, 13.22 and 19.07, respectively. Poçan et al. (2015) reported the minimum and maximum b* values as 14.68 and 19.30, whereas Kara et al. (2021) determined the maximum, minimum and mean b* values of sucuk samples as 30.63, 18.45 and 23.21, respectively. Our results are in the same line with these previous studies. Differences in these similar studies may be attributed to differences in formulations, type of sucuk and variations in the processes during production and post-production periods.

Textural analysis

Texture Profile Analysis and Warner-Bratzler Shear Force

Textural properties of food products is one the most important parameters for its quality. Stabilizers, emulgators, thickeners and some other ingredients for structure defending effect the texture of food via various active mechanisms (Khan et al. 2018). Warner-Bratzler shear force is defined as the minimum force that is required to cut the food (Bratcher 2004). In a similar study by Kara et al. (2021) textural properties were reported as: hardness; 5320.21, adhesiveness;-24.24, springiness; 0.78, cohesiveness; 0.62, gumminess; 3338.62, chewiness; 2703.93 and resilience; 0.22.

Microbiological Analysis

Total Aerobic Mesophilic Bacteria Counts

There is no legal limits for sucuk and heat treated sucuk in Turkish Food Codex Microbiological Criteria Regulation and TS 1070 Sucuk Standard (TS 2002). However, in a sucuk that is produced under properly hygienic conditions, TAMB counts should be under 6 log cfu/g (İnal 1992).

In a similar study by Pehlivanoğlu et al. (2015) the minimum TAMB counts were reported to be <1 log cfu/g, maximum counts 2.03 log cfu/g and mean counts 1.23 log cfu/g. Öksüztepe et al. (2011) claimed the minimum, maximum and mean TAMB counts that were sold in the Elazığ region as; 7.48 log cfu/g, 9.90 log cfu/g and 8.75 log cfu/g, respectively.

There have been many studies on this subject until today. Current results are in line with some previous studies (Pehlivanoğlu et al. 2015) whereas they are lower than some other studies (Öksüztepe et al. 2011, Çon et al. 2002).

These variations between current results and previous researches could be the consequence of modifications in production technologies and storage conditions. Microbiological activities play an essential role in the formation of typical properties of sucuk in the ripening period. Microbial load comes from the raw material in the sucuk dough (fat, spices and meat) and starter cultures. Increased acidity, pH and water activity as a result of lactic acid bacteria (LAB) activities, cause decreases in the aerobic mesophilic bacteria counts depending on the alteration in the ripening period (Nazlı 1998, Bozkurt and Erkmen 2002).

Lactic Acid Bacteria (LAB) Counts

One of the most important constituents of sucuk microflora is lactic acid bacteria (LAB). In addition to influencing the formation of desired tastes and aromas, LAB also affects the hygienic quality of sucuk by preventing the growth of additional bacteria through the synthesis of numerous antimicrobial metabolic products. As a result of carbohydrate breakdown during fermentation, pH decreases with the accumulation of organic acids, mainly lactic acid. Lactobacillus become the dominant microflora in the media due to the decreased water activity with the addition of salt into the sucuk dough and ripening temperature. Lactobacillus not only decreases the pH, but also effects the taste and aroma (Özdemir 1999, Fadda et al. 1999). Nevertheless, Turkish Food Codex Microbiological Criteria Regulation (TGK 2012) or TS 1070 Sucuk Standard (2002) have no limitations on the LAB counts that should be present in sucuk and heat-treated sucuk.

Previously conducted studies by Çon and Gökalp (1998), Pehlivanoğlu et al. (2015) and Öksüztepe et al. (2011) reported the mean LAB counts as; 8.66 log cfu/g, 7 log cfu/g and 8.56 log cfu/g, respectively. Current results are lower than these reported ones.

High amounts of LAB in sucuk may cause excessive decreases in pH and sour taste. It was reported that the addition of nitrite/nitrate, fermentation period and storage temperatures are effective on LAB growth (Zhao et al. 2011). Besides, LAB counts may also change according to food additives during storage period, amount, type and activity of starter cultures (Baytal 2023). Correspondingly, there may be differences in the number and activity of starter cultures.

Total Yeast and Mold Counts (TYM)

Some species of molds and yeast can affect color, aroma and odour whereas some of them cause deterioration (Şenol and Nazlı 1996, Yıldırım 1996). In the Turkish Food Codex Microbiological Criteria Regulation (TGK 2012) and TS 1070 (2002), maximum limits of total yeast and mold counts were approved as 10 in 1 g sample. Accordingly, 18 (60 %) of 30 samples are over the limit of TS 1070 Sucuk Standard (TS 1070 2002).

Mean total yeast and mold counts of previous studies by Şenol and Nazlı (1996), Günşen et al. (2001), Kök et al. (2007), Pehlivanoğlu et al. (2019) ; >5 log cfu/g and Öksüztepe et al. (2011) were reported as 4.72 log cfu/g, 3.28 log cfu/g, 3.00 log cfu/g, >5 log cfu/g, and 3.08 log cfu/g, respectively. Current results are lower than these counts.

In the first days of ripening, depending on the environmental aspects, mold and yeast counts increase rapidly and reach to 6 log cfu/g. Following days, along with the decreases in pH, water activity and redox potential value, mold and yeast counts decrease towards the end of ripening, and they become more concentrated against the exterior surface of sucuk (Tekinşen et al. 1982).

Total Coliform Bacteria Counts

Coliform group bacteria, a member of the family Enterobacteriaceae, are commonly an indicator of cross-contamination during the production process. They are capable of converting carbohydrate substrates into acid and may also reduce nitrate to nitrite and degrade the proteins (Yıldırım 1996). However, it was stated that coliform counts should not be high because they are correlated to being an indicator of probable hygiene and technological mistakes in final products (Nazlı 1995). Dominant microflora in traditional fermented meat products are highly related with the quality and the safety of the foodstuff.

In similar studies by Çon et al. (2002) stated mean coliform count as >6 log cfu/g, Öksüztepe et al. (2011) reported coliform counts ranged between 1.10- 2.6 log cfu/g, Pehlivanoğlu et al. (2015) indicated coliform counts in the range of <1 to 2.67 log cfu/g. Detected values are quite below the counts stated by previous researches. Turkish Food Codex Microbiological Criteria Regulation (TGK 2012) and TS 1070 (2002) limited the coliform counts to 10 in 1 g sample according to the most probable number method. Eventually, our samples have lower coliform counts than TS 1070 legislation (TS 1070 2002).

The presence of hygiene indicator microorganisms, especially coliforms, over a specific level in sucuk may be a result of inadequate or inaccurate ripening, the supply of raw materials in unhygienic conditions, or contamination during the process (Sancak et al. 1996).

***Staphylococcus aureus* Counts**

Öksüztepe et al. (2011) and Pehlivanoğlu et al. (2015) reported *S. aureus* counts of sucuk samples as 3.99 log cfu/g and 4.84 log cfu/g, respectively. Our current results are lower than these values.

According to the Turkish Food Codex Microbiological Criteria Regulation (TGK 2012) and TS 1070 (2002), the maximum number of *S. aureus* should be 100 in 1 g sample. All counts are below the legal limit in force. It was also determined that none of the sucuk samples contained *E. coli, Salmonella* spp. or *Listeria monocytogenes*.

CONCLUSIONS

The present study was aimed to determine the physicochemical and microbiological quality characteristics of the world-famous Afyon sucuk and its compliance with Communiqué on Turkish Food Codex Meat and Meat Products, Turkish Food Codex Microbiological Criteria Regulation (TGK 2012) and TS 1070 Sucuk Standard (TS 2002).

In terms of pH, protein content and fat content; 83.3%, 26.66% and 16.66% of current sucuk samples did not comply with Communiqué on Turkish Food Codex Meat and Meat Products, respectively. On the other hand, ash and salt contents are in accordance with legal regulations.

Total aerobic mesophilic bacteria and total yeast/ mold counts of 60% of sucuk samples are exceeding the legal limits in TS 1070 Sucuk Standard. Besides that, total *Coliforms*, *S.aureus*, *E.coli, Salmonella spp.* and *L.monocytogenes* counts are within the limits in Turkish Food Codex Meat and Meat Products, Turkish Food Codex Microbiological Criteria Regulation (TGK 2012and TS 1070 Sucuk Standard (TS 2002).

Especially, the physicochemical quality parameters were determined to be over the specified values in force in this research. Therefore, tightening the inspection mechanism must be in process. The absence of some of the physicochemical and microbiological quality criteria in related regulations rarifies standard production. Additionally, HACCP and GMP requirements need to be followed throughout the entire production process to ensure that products are safe and meet microbiologic standards.

Conflict of interest: The authors have no conflicts of interest to report.

Authors' Contributions: RŞ and HY contributed to the project idea, design and execution of the study. HY, GA, ÇA and AJD contributed to the acquisition of data. RŞ, HY and GA analysed the data. GA, ÇA and AJD drafted and wrote the manuscript. RŞ reviewed the manuscript critically. All authors have read and approved the finalized manuscript.

Ethical approval: This study is not subject to the permission of HADYEK in accordance with the "Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees" 8 (k). The data, information and documents presented in this article were obtained within the framework of academic and ethical rules.

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