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EFFECTS OF FERMENTATION AND COOKING ON THE QUALITY OF SAUSAGES AND BURGERS

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ABSTRACT

The effects of fermentation and cooking on the quality of burgers and sausages were investigated. In the case of the burger samples, relative moisture content decreased by cooking, whereas the relative content of fat, protein, and ash increased slightly. Fermentation also reduced the relative moisture content, whereas the relative content of fat, protein, and ash increased slightly. Similar results were obtained for the sausage samples. Overall, sensory evaluations indicated that fermented, cooked samples yielded maximum palatability in both burgers and sausages. Sixty volatile chemicals were identified in the headspace of the burger and 48 in the headspace of the sausage samples. Organosulfur compounds comprised the greatest percentage in both the burger and the sausage samples. Various terpenes that were formed from seasonings and spices were also identified in the samples. The present study demonstrates that fermentation and cooking play an important role in the preparation of high-quality burgers and sausages.

Keywords: Cooking effect, fermentation effect, meat burger, meat quality, sausage.

INTRODUCTION

Historically, fermentation techniques have been used to preserve a wide variety of food products, including meat (Latorre et.al., 2008). The quality of sausages prepared by traditional methods in Mediterranean countries usually suffered slightly from acidification (pH >5.4) caused by the autochthonous flora. However, the products produced by this traditional method have been appreciated by consumers because of the products' sensorial characteristics (Talon et.al., 2002). The flavor chemicals involved in traditional fermentation methods play an important role in consumers' preferences for particular food products.

The flavor chemicals in a fermented sausage are yielded from components present in the raw sausage, such as proteins, carbohydrates, and lipids, upon fermentation and bacterial metabolism (Tjener, 2007). In addition to these, diverse ranges of microorganisms are used in sausage production. The diversity of microorganisms used during sausage manufacturing is essential for the formation of characteristic sausage flavors. The main microorganisms present in traditional dry-fermented sausages are lactic acid bacteria (*staphylococcus* and *kocuria*), which produce various chemicals; including volatile flavor compounds and pigments (Ammor and Mayo, 2007). Modifications in the sausage flavor profile have been achieved by changing microbial composition (Tjener, 2007). More than 400 volatile compounds have been reported in fermented sausages, but only a few compounds with a low-odor threshold are known to contribute to characteristic sausage flavors (Latorre et.al., 2011 and Rivas et.al., 2012).

Lipid components play an important role in the preparation of highly palatable sausages because they produce preferable flavors, textures, and tastes via fermentation and also work as a vehicle for aroma compounds (Leland, 1997). Therefore, high-lipid content (40%–50%) in the raw meat is recommended when making dry-fermented sausages (Zanardi et.al., 2004).

Controversial issues exist surrounding high fat–content food products because excessive fat intake is known to cause various diseases, such as arteriosclerosis.[9] However, sausages with high-fat content still have the highest acceptability scores because of the palatability factors mentioned above (Olivares et.al., 2010).

In the present study, the effects of fermentation using lactic acid bacteria on the volatile profiles of sausages and burgers were investigated to find ways of preparing highly palatable sausages.

MATERIALS AND METHODS

MATERIALS

Frozen New Zealand beef and all the ingredients for sausage preparation were purchased from a local market (Dokki, Cairo, Egypt). Isolated soy protein was obtained from soybean plants at the Agricultural Research Center in Cairo, Egypt. Sodium tripolyphosphate ($Na_5P_3O_{10}$) was purchased from the Sigma-Aldrich Company (St. Louis, MO, USA) and potato starch from the Starch and Glucose Company (Cairo, Egypt). All authentic chemicals for volatile analysis were gifts from Takata Koryo Co., Ltd. (Hyogo, Japan).

SAMPLE PREPARATIONS

The formulations of burgers and sausages used in the present study are shown in Table I. The beef (500 g) was manually cut using a band saw (JG-210) and minced through a 4 mm–diameter grinder plate. The minced beef was stored at −18 °C until used. Salt (2%) was added to frozen minced beef (49.0 g) and mixed with a Hobart mixer for 3 min. Isolated soy protein (50 g) was blended with water and fat at a ratio of 1:5:5 (w/w) using a mixer. The emulsion prepared was called pre-emulsion and kept at 2 °C–5 °C.

Sodium tripolyphosphate, spices (black pepper, garlic powder, onion powder, and ground cayenne pepper), potato starch, and textured vegetable protein were mixed in water, and then the pre-emulsion was added according to the formulations shown in Table 1. Beef burgers (70 g each) were prepared from the finished meat batters. The cooked burgers were prepared by heating on a hot plate for 7–8 min, until the internal temperature reached 74 °C ± 1 °C.

Table I -Formulations of Beef Burger And Sausage (%)

Burger			Sausage		
Ingredients	**Non-fermented**	**Fermented**	**Ingredients**	**Non-fermented**	**Fermented**
Beef	49.0	49.0	Minced meat	70.0	70.0
Beer fat	15.0	15.0	Vegetable hydrogenated fat	5.0	5.0
Water	22.5	12.5	Sodium chloride	2.5	2.5
Textured vegetable protein	5.0	5.0	Sugar	1.5	1.5
Starch	3.0	3.0	Polyphosphate	0.2	0.2
Isolated soy protein	3.0	3.0	Monosodium glutamate	0.2	0.2
Yoghourt	0.0	10.0	Yoghourt	0.0	10.0
Salt	1.1	1.1	Color solution**	0.13	0.13
Sodium tripolyphosphate	0.3	0.3	Spices mixture	1.1	1.1
Spices and seasoning	1.1	1.1	Corn starch	9.0	9.0
			Crushed ice	10.0	10.0
Total	100.0	100.0	Total	1.00.0	100.0

Sausages were manufactured in a pilot plant according to a traditional recipe for Pascua Longaniza sausage (Alesson *et.al.,* 2004). The meat and fat were ground through a 6-mm plate (Cato, Sabadell, Spain) and then mixed with the other ingredients according to the amounts shown in Table 2. The amounts of other ingredients used are relative to the amount of meat used (1 kg). The sample mixture was stuffed in lamb casings (20 mm–25 mm in diameter). Drying was conducted at 15 °C and 75% relative humidity for 5 days. The cooking method was the same for the burgers.

Table II -Volatile Compounds Identified in the Burger Samples

Relative peak area %					
Compound	**I[a]**	**Non-fermented**		**Fermented**	
		Uncooked	**Cooked**	**Uncooked**	**Cooked**
Organosulfur compounds					
Methane thiol	606	13.02	16.97	12.07	32.32
Dimethyl sulfide	617	18.88	20.16	12.90	21.28

Dimethyl disulfide	756	-	1.72	-	4.67
2-Methylthiazole	842	1.82	20.64	-	7.62
Dially disulfide	1097	042	0.12	1.36	0.42
Dially trisulfide	1294	0.90	0.07	1.88	-
Subtotal		34.10	29.68	28.21	66.52
Aldehydes and Ketones					
3-Methyl butanal	645	5.41	8.60	3.58	17.87
2-Methyl butanal	678	-2.19	1.00	-	-
-	828	-	0.15	-	-
Octanal	1006	0.29	7.81	-	1.33
(E)-Nonenal	1165	-	-	0.56	-
(Z)-2-Decenal	1248	-	-	0.75	-
2-Pentadecanone	1690	0.37	-	0.35	0.10
Pentadecanal	1716	0.15	0.15	1.70	-
Hexadecanal	1810	1.03	-	0.33	0.54
2-Heptadecanone	1906	0.26	0.13	0.91	0.40
9-Octadecenal	1991	16.93	5.77	-	0.22
Subtotal		24.55	24.65	9.84	20.46
Acids					
Octanoic acid	1195	0.36	0.15	3.50	0.44
1386	1386	1.47	0.50	7.43	0.94
Dodecanoic acid	1573	1.28	0.53	4.96	0.44
Tetradecanoic acid	1762	1.27	0.50	3.54	0.67
Hexadecenoic acid	1949	2.05	0.40	4.75	0.22
Hexadecanoic acid	1987	25.71	0.35	6.68	2.23
Subtal		32.14	2.43	30.86	4.94
Esters					
Ethyl hexanoate	1014	-	6.56	-	0.19
Methyl decanoate	1328	0.28	0.08	0.42	-
Ethyl dodecanoate	1592	1.04	0.39	5.52	0.76
Tetradecanoic acid methyl ester	1726	0.37	0.09	0.71	-
Tetradecanoic acid ethyl ester	1791	0.59	0.21	0.59	0.56
Hexadecanoic acid methyl ester	1926	1.09	0.59	2.52	1.47
9,12-Octadecadienoic acid methyl ester	2111	-	-	0.38	-
Subtotal		3.37	7.92	16.33	2.98
Alcohols					
3-Methyl butanol	744	-	1.73	-	-
1-Octen-3-ol	1006	-	0.28	-	0.34
1-Hexadecanol	1888	2.52	-	0.58	0.11
(Z)-9-Octadecen-1-ol	2072	-	-	0.36	-
1-Octadecanol	2098	-	-	2.93	-
Subtotal		2.52	2.01	3.87	0.45
Terpenes					
α-Pinene	936	-	0.31	-	0.50
d-Limonene	1033	0.92	0.31	2.40	1.01

δ-elemene	1340	0.18	-	0.87	-
α-Terpinyl acetate	1364	0.66	0.33	3.65	0.31
β-Caryophyllene	1438	0.39	-	-	1.16
Germacrene-D	1480	0.43	0.15	1.74	0.10
β-Ionone	1488	-	-	0.80	0.18
δ-Cadinene	1520	0.11	0.07	0.35	0.23
Subtotal		2.69	0.86	9.81	2.99
Subtotal		-	1.27	-	-
Miscellaneous compounds					
Pyrazine	731	-	0.46	-	0.77
Methyl pyrazine	828	-	0.34	-	-
4-Methyl phenol	1073	-	0.33	-	-
2-Methoxy phenol (Guaiacol)	1087	-	0.94	-	-
Octadecane	1798	0.54	-	0.57	-
Subtotal		0.54	2.07	0.57	0.77

[a]Kovats Index on DB-5

DETERMINATION OF COMPOSITION OF MOISTURE, FAT, PROTEIN, AND ASH IN THE BURGER AND SAUSAGE SAMPLES

The composition of each element was determined according to the Association of Analytical Communities (AOAC) method (2000); the section numbers were 925.10 for moisture, 920.85 for fat, 920.87 for protein, and 923.03 for ash.

MEASUREMENT OF PHYSICAL CHANGES IN BURGER SAMPLES

Cooking characteristics were determined according to a previously reported method,[11] using the following equation:

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked sample}}{\text{Weight of uncooked sample}} \times 100$$

Shrinkage (%) was calculated as described by American Meat Science Association (1995), using the following equation:

$$\text{Shrinkage (\%)} = \frac{(a - b) + (c - d)}{(a - c)} \times 100$$

Where *a* is thickness of uncooked burger, *b* is thickness of cooked burger, *c* is diameter of uncooked burger, and *d* is diameter of cooked burger.

COLOR MEASUREMENT OF FERMENTED AND NONFERMENTED BURGER AND SAUSAGE SAMPLES

Color measurement was performed according to previously reported methods (Bochi *et.al.,* 2008 and Chen *et.al.,* 1997), using a colorimeter (LabScan XE, HunterLab, Murnau, Germany), and standardized with a white tile of Hunter Lab color standard (LX No. 16379): X = 77.26, Y = –81.94, and Z = 88.14 (L* = 92.46, a* = –0.86, b* = –0.16). The measured color parameters were L* (lightness), a* (redness), and b* (yellowness). The saturation index (C*) was calculated as $(a^{*2} + b^{*2})^{1/2}$, which indicates color intensity or color purity of a sample. The L* scale ranges from 0 (black) to 100 (white); the a* scale extends from a negative value (green hue) to a* positive value (red hue), and the b* scale ranges from negative blue to positive yellow. The redness index H* was (a*/b*), which was used to evaluate apparent changes in redness. The total color difference between uncooked and cooked samples (ΩE) was calculated as $(\Omega L^{*2} + \Omega a^{*2} + \Omega b^{*2})^{1/2}$. ΩL*, Ωa*, and Ωb are differences between uncooked and cooked samples in HunterLab color values.

SENSORY EVALUATION

Sensory evaluation was performed by 10 trained consumers consisting of students and staff in the Food Technology Department, National Research Center (Dokki, Giza, Egypt) according to a previously reported method (Paulus *et.al.,* 1979). The evaluation of samples of burger and sausage for color, odor, taste, and texture was conducted for overall acceptance on a 7-point scale (1 = strongly dislike, 4 = neither like nor dislike, and 7 = strongly like). Significance was established at $P < 0.05$ unless otherwise indicated.

STATISTICAL ANALYSIS

Statistical analysis of the data was performed using analysis of variance (ANOVA) and Duncan's multiple range test with SAS version 6.12 (SAS, 1989).

ISOLATION AND IDENTIFICATION OF HEADSPACE VOLATILES

The volatiles in the headspace of each sample were collected using a dynamic headspace system. The samples (200 g) were purged with a nitrogen gas stream (>99.99%) at 100 mL min^{-1} for 1 h, and the volatiles were trapped in a 500 mL diethyl ether/pentane (1/1, v/v) solution at –10 °C.

After the solution was dried over anhydrous sodium sulfate for 1 h, it was condensed to 0.5 mL in volume. The sample was analyzed by GC and GC/MS for volatile components.

Compounds in the headspace samples were identified by comparison with the Kovats gas chromatographic retention index (KI) and mass spectral fragmentation pattern of each GC component to those of authentic compounds. Identification of the GC components was also confirmed by NIST AMDIS version 2.1 software.

A Hewlett Packard (HP) model 5890 gas chromatograph equipped with a 60 m × 0.32 mm i.d. (d_f = 0.25 □ m) DB-5 bonded-phase fused-silica capillary column (Agilent, Folsom, CA) and a flame ionization detector (FID) were used. The oven temperature was 50 °C held for 5 min, then programmed to rise to 250 °C at 4 °C min^{-1}. Helium carrier gas flow rate was 1.1 mL min^{-1}. The injector and detector temperatures were 220 °C and 250 °C, respectively.

An HP model 5890 GC interfaced to an HP 5970 mass selective detector (GC/MS) was used for mass spectral identification of the GC components at an MS ionization voltage of 70 eV, and the mass range was m/z = 39 – 400 a.m.u. The GC conditions were as described above.

RESULTS AND DISCUSSION

RELATIVE COMPOSITION OF MOISTURE, FAT, PROTEIN, AND ASH IN BURGER AND SAUSAGE SAMPLES

Figure 1 shows the relative proportions of moisture, fat, protein, and ash in the burger (A) and sausage (B) samples. In the case of the burger samples, relative moisture content decreased from 73.15% ± 1.22% to 55.19% ± 1.06% in nonfermented burgers and 66.13% ± 0.65% to 50.22% ± 0.67% in fermented burgers upon cooking, whereas the relative content of fat, protein, and ash increased slightly. Fermentation also reduced the relative moisture content from 73.15% ± 1.22% to 66.13% ± 0.65% in uncooked burgers and 55.19% ± 1.06% to 50.22% ± 0.67% in cooked burgers.

Cooking reduced the relative proportion of moisture from 67.04% ± 1.45% to 52.25% ± 1.67% in nonfermented sausages and 66.13% ± 1.01% to 50.22% ± 1.35% in fermented sausages. The moisture content was also reduced slightly by fermentation. Contrarily, cooking increased the relative proportions of fat, protein, and ash in both nonfermented and fermented sausages.

EFFECTS OF COOKING AND FERMENTATION ON PHYSICAL CHARACTERISTICS OF BURGER SAMPLES

The yields of cooked, nonfermented and fermented burger samples were 69.10%^{b} ± 1.17% and 71.60%^{a} ± 1.22%, respectively. Shrinkages after cooking were 18.23%^{a} ± 0.25% (nonfermented burger samples) and 16.36%^{b} ± 0.32% (fermented burger samples), respectively, indicating that fermentation did not significantly change the cooking yield or shrinkage values of cooked burger samples. The weights of the fermented burgers (uncooked fermented, 60.35 g ± 9.08 g; cooked fermented, 43.06 g ± 7.37 g) were significantly greater than those of the nonfermented burgers (uncooked, nonfermented, 47.9 g ± 1.67 g; cooked, nonfermented, 34.33 g ± 3.01 g).

RESULTS OF COLOR MEASUREMENTS OF BURGER AND SAUSAGE SAMPLES

Figure 2 shows the results of color measurement of the burger and sausage samples. In the case of the burger samples, generally all values were decreased by cooking. In particular, lightness (L*) values decreased perceptibly in the cooking process in both the nonfermented (from 43.17 ± 0.77 to 26.53 ± 1.21) and the fermented (from 47.11 ± 1.18 to 30.29 ± 2.22) samples. In the case of the sausage samples, change of color properties was similar to that of the burger samples.

SENSORY EVALUATION OF COOKED BURGER AND SAUSAGE SAMPLES

Figure 3 shows the results of sensory evaluations of cooked burger samples and cooked sausage samples. In the case of the burger samples, taste and texture values were increased by fermentation; although color value was reduced from 8.56 ± 0.19 to 8.22 ± 0.12 (that is, by 4.0%), this is not a significant change. In the case of the sausage samples, all values were increased by fermentation: 6.8% for color, 14.5% for odor, 20.8% for taste, and 15.8% for texture.

VOLATILE COMPOUNDS IDENTIFIED IN BURGER SAMPLES

Table II shows 60 volatile compounds identified in the burger samples. The values are GC peak area% excluding solvent peak. The numbers of compounds identified in each chemical group were 6 organosulfur compounds, 14 aldehydes/ketones, 6 acids, 10 esters, 4 alcohols, 14 terpenes, and 6 miscellaneous compounds. Volatiles found in fermented burger samples are reported for the first time in the present study. The organosulfur compounds comprised the greatest percentage of volatiles in all samples, ranging from 25.34% (fermented, uncooked) to 92.42% (fermented, cooked). The total proportion of organosulfur compounds increased significantly by cooking; in particular, dimethylsulfide and 2-methylthiazole in one fermented sample increased from 0.15% to 20.67% and from 3.47% to 53.07%, respectively, upon cooking.

LSD at 0.05 was 0.44 from moisture, 0.32 from fat, 0.39 from protein, and 0.11 from ash in the burger samples. LSD at 0.05 was 1.01 from moisture, 0.52 from fat, 0.83 from protein, and 0.17 from ash in the sausage samples.

Table III - Volatile Compounds Identified in the Sausage Samples

Compound	I[a]	Relative peak area %			
		Non-fermented		Fermented	
		Uncooked	Cooked	Uncooked	Cooked
Organosulfur compounds					
Methane thiol	606	7.90	18.7	10.42	0.72
Dimethyl sulfide	617	12.05	13.41	10.71	17.96
Dimethyl disulfide	756	1.16	-	0.15	20.67
2-Methylthiazole	842	21.45	-	3.47	53.07
Dially disulfide	1097	0.29	-	0.46	-
Dially trisulfide	1294	-	-	0.13	-
Subtotal		42.85	32.11	25.34	92.42
Aldehydes and Ketones					
3-Methyl butanal	645	5.21	3.03	6.03	-
2-Methyl butanal	678	10.13	-	0.19	0.18
2,3-Butandione	724	0.25	-	-	-
2.3-Pentadione	744	6.75	-	-	-
Octanal	1006	7.55	-	-	-
(E)2-Nonenal	1165	0.31	-	0.58	-
(Z)-2-Decenal	1248	0.14	0.50	0.39	-
2.4-Decadienal	1319	-	-	0.38	-
Tetradecanal	1610	-	0.26	0.16	-
2-Pentadecanone	1690	0.03	0.79	1.08	-
Pentadecanal	1716	-	0.55	0.07	-
Hexadecanal	1810	0.16	1.76	0.74	-
2-Heptadecanone	1906	0.20	0.29	0.13	-
9-Octadecenal	1991	2.41	1.25	2.44	1.22
Subtotal		33.14	8.43	12.19	1.40
Acids					
Acetic acid	701	0.41	-	-	0.23
Octanoic acid	1195	0.10	0.42	3.50	0.44
Dodecanoic acid	1573	-	0.38	1.74	-
Tetradecanoic acid	1762	0.19	1.77	0.20	-
9-Hexadecenoic acid	1949	0.24	1.89	0.37	-
Hexadecanoic acid	1987	4.46	20.40	2.33	-
Subtal		5.13	24.86	8.14	4.94
Esters					
Methyl-2-methylbutanoate	818	0.79	-	0.07	-
Ethyl-2-methylbutanoate	858	1.91	-	0.39	-
Ethyl hexanoate	1014	0.79	-	2.25	1.48
Methyl-3-(methylthio)propanoatte	1020	7.04	-	2.25	1.48
Methyl decanoate	1328	-	-	0.24	-
Ethyl dodecanoate	1592	0.19	1.47	0.28	-
Tetradecanoic acid methyl ester	1726	-	1.00	0.37	-
Tetradecanoic acid ethyl ester	1791	0.13	3.99	-	-
Hexadecanoic acid methyl ester	1926	0.22	1.39	0.06	0.19
9,12-Octadecadienoic acid methyl ester	2111	-	-	0.38	-
Subtotal		11.07	7.85	4.04	1.67
Alcohols					
3-Methyl butanol	744	0.71	-	0.12	-
1-Hexanol	870	2.26	1.27	-	-
1-Octen-3-ol	1006	1.09	-	2.63	1.32
1-Hexadecanol	1888	0.48	2.42	0.42	-

Subtotal		4.54	3.69	3.17	1.32
Terpenes					
α-Pinene	936	0.46	-	0.19	-
d-Limonene	1033	0.99	-	-	-
1,8-Cineol	1040	0.15	0.45	-	-
γ--Terpinene	1073	0.24	-	0.27	-
Linalool	1103	0.10	-	0.23	-
Anethol	1287	-	-	0.13	-
δ-elemene	1340	0.21	1.66	0.17	-
α-Terpinyl acetate	1364	-	1.41	3.81	-
β-Caryophyllene	1438	-	0.40	1.26	-
α-Humulene	1458	-	0.80	0.30	-
Germacrene-D	1480	0.10	0.58	5.00	0.13
β-Ionone	1488	-	-	1.38	0.18
δ-Cadinene	1520	0.05	8.56	32.27	2.10
γ-Cadinene	1538	-	0.17	0.33	-
Subtotal		2.30	14.03	45.32	2.41
Miscellaneous compounds					
Pentadecane	1503	-	-	0.63	-
Hexadecane	1592	0.18	1.43	0.26	-
Heptadecane	1698	-	-	0.95	-
4-Methyl phenol	1073	0.12	-	-	-
2-Methoxy phenol (Guaiacol)	1087	0.04	-	0.07	-
Octadecane	1798	0.10	7.42	-	-
Subtotal		0.44	8.85	1.91	0.0

[a]Kovats Index on DB-5

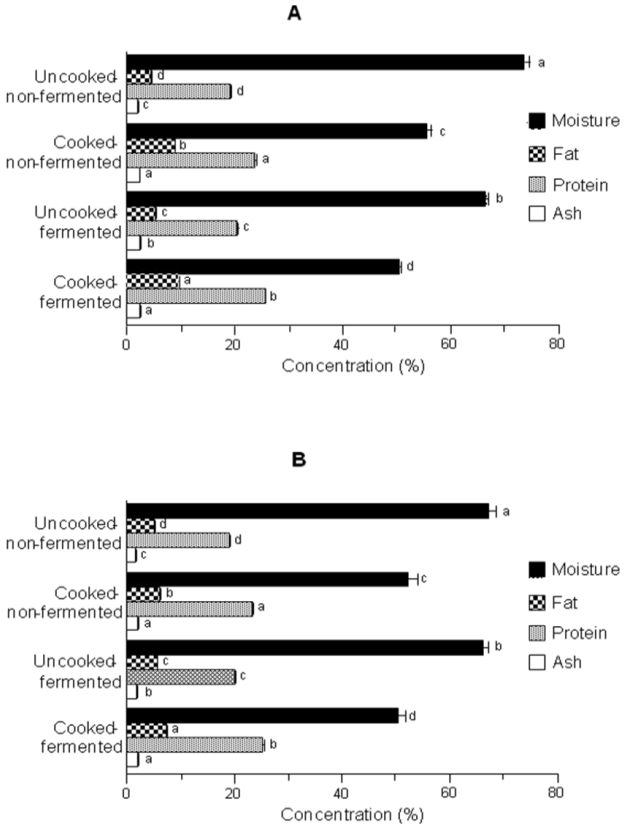

Figure 1: Relative composition of moisture, fat, protein, and ash in burger and sausage samples.

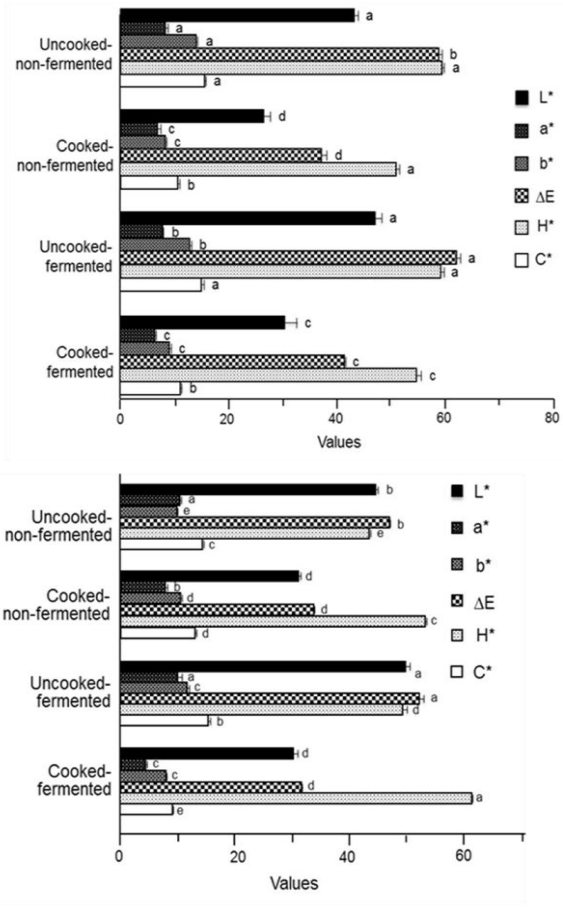

Figure 2: Results of color measurements on burger (A) and sausage (B) samples.

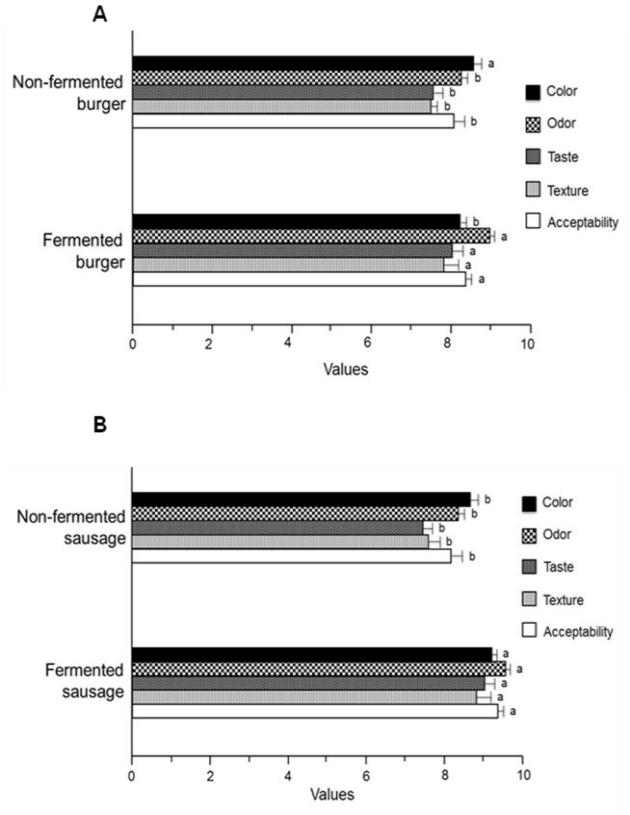

Figure 3: Results of sensory evaluations of cooked burger samples (A) and cooked sausage samples (B).

VOLATILE COMPOUNDS IDENTIFIED IN SAUSAGE SAMPLES

LSD at 0.05 was 3.52 from L*, 1.11 from a*, 0.19 from b*, 3.65 from □ E, 3.16 from H*, and 0.65 from C* in the burger samples. LSD at 0.05 was 3.65 from L*, 1.35 from a*, 1.18 from b*, 2.13 from □ E, 2.65 from H*, and 0.65 from C* in the sausage samples.

Figure 3: Results of sensory evaluations on cooked burger samples and cooked sausage samples. LSD at 0.05 was 0.04 from color, 0.04 from odor, 0.04 from taste, 0.03 from texture, and 0.03 from acceptability in the burger samples. LSD at 0.05 was 0.65 from color, 0.73 from odor, 1.14 from taste, 0.63 from texture, and 1.03 from acceptability in the sausage samples.

Table III shows 48 volatile compounds identified in the sausage samples. The values are GC peak area% excluding solvent peak. The numbers of compounds identified in each chemical group were 6 organosulfur compounds, 11 aldehydes/ketones, 6 acids, 7 esters, 5 alcohols, 8 terpenes, and 5 miscellaneous compounds. Organosulfur compounds comprised the greatest proportion of volatiles, ranging from 28.21% (fermented, uncooked) to 66.52% (fermented, cooked). Organic acids are the second major group of compounds in the uncooked sausage samples, comprising 32.14% and 30.86% in unfermented and fermented samples, respectively. However, their composition decreased drastically in cooking (2.43% and 4.94%, respectively). Obvious increases of methanethiol composition upon cooking were observed in the present study, from 13.02% to 16.97% in nonfermented samples and 12.07% to 32.32% in fermented samples. The total amount of aldehydes and ketones in the nonfermented sausage samples was not changed by cooking, whereas the total amount increased from 9.84% to 20.46% when the fermented samples were cooked.

DISCUSSION

Fermentation slightly increased the relative content of fat, protein, and ash in uncooked burgers. These results, which are consistent with a previous report (Weber et.al., 2008), indicate that cooking and fermentation processes change the physical characteristics of burgers. In the case of the sausage samples, similar results were obtained. The results in the present study and in a previous study indicate that cooking and fermentation change the relative composition of the sausage samples (Alesson *et.al*, 2004).

In the case of physical characteristic changes by cooking and fermentation upon burger samples, the same trends were observed in the case of their diameters. Cooking increased thickness slightly in both nonfermented and fermented burgers. These results and the previously reported results from catfish burgers indicate that cooking and fermentation play an important role associated with the burgers' quality and physical characteristics (Hassab *et.al.*, 2009).

Color is one of the most important factors in judging the palatability of foods and is likely to directly affect consumers' preferences. It is reasonable that lightness decreases in cooking, however, and decreased lightness does not always reduce palatability. Similar changes for L* and b* values were reported for uncooked and grilled catfish burgers (Bochi *et.al.*, 2008). Decreased lightness on cooking was observed as a result of the reduction of water content and concentration of components, which contribute to product redness (Alesson *et.al*, 2004).

Organoleptic evaluation is generally the final guide to the quality of a food product from the consumer's point of view. Organoleptic factors, including color, odor, taste, and texture, play the most important role in determining the acceptability and palatability of products for consumers. By fermentation, acceptability of burger and sausage samples was increased by 3.5% and 14.4%, respectively, suggesting that fermentation increases the palatability of burgers and sausages slightly. These results suggest that fermentation significantly increases the palatability of sausages. These results suggest that organoleptic changes were caused by cooking and fermentation, which also promote the formation of volatile compounds.

It is proposed that the volatile sulfur compounds found in burger samples are formed from thermal degradation of sulfur-containing amino acids and proteins present in beef and additional ingredients in the samples, such as soybean. Some of these compounds contribute

characteristic sulfurous flavors to cooked foods (Arctander, 1969). These results are consistent with previous reports (Abdel et.al., 2010 and Wu, 2002). It is interesting that fermentation increased the amount of terpenes from 2.30% to 45.32% in uncooked samples. In particular, □-cardinene increased from 0.05% to 32.27%. These terpenes may form from some burger ingredients, such as spices and seasonings, but it is difficult to rationalize the production of these terpenes. However, a previous study also reported that 24 terpenes were proposed to have formed from spices and seasonings in fermented meat (Ansorena et.al., 2001).

In the case of sausage samples, sulfur compounds were formed from the sulfur-containing amino acids present in the meat and vegetable proteins and seasonings (onion and garlic) in the sausage formulation (Table 1) as in the case of the fermented burger samples,. These low molecular–weight organosulfur compounds were proposed to form from methionine by the Strecker degradation in cooking.[21]

The formation of methenthiol is consistent with a previous study, which reported an increase in methanethiol in uncooked sausage during heat treatment (Wu, 2002). Methanethiol is also reported in cod and stewed beef juice and, as a chemical, contributes a sulfurous odor to cooked meats (Milo, 1995). The same phenomena were observed in the case of dimethyl (corn-like flavor) and 2-methylthiazole (cooked meat flavor). It is also proposed that thiazoles are formed from the thermal degradation of sulfur-containing compounds, such as cysteine and thiamine (Elmore *et.al.*, 2001). The results in the present study are consistent with previous reports (Abdel et.al., 2010 and Jerkovic et.al., 2010).

A previous study also reported that acids comprised 60% of the volatiles found in dry-fermented sausage (Ansorena et.al., 2001). These acids are proposed to form from the hydrolysis of triacylglycerols/phospholipids and degradation of lipids (Girard, 1991). Carboxylic acids are known to produce esters (Shahidi et.al., 1986), which comprised 16.33% of the volatiles from the uncooked fermented samples in the present study, via esterification. Some ethylesters, including ethylhexanoate, have low-odor threshold values and were associated with a fruity aroma, which can mask rancid odors in fermented sausage (Marco et.al., 2006).

Low molecular–weight aldehydes and ketones are known as flavor chemicals. In particular, 3-methyl butanal, which is proposed to form from isoleucine (Herranz et.al., 2005), increased 5-fold in the cooked, fermented samples. Straight chain aldehydes (C_5–C_{18}), identified in fermented sausage samples, are proposed to form from a corresponding free fatty acid released from triglycerides (Ansorena et.al., 2001). Various aldehydes and ketones formed from lipids have been known to contribute characteristic flavors to fermented sausages (Ordontez et.al., 1999).

The presence of terpenes in meats is rather unusual, but their major sources are spices and seasonings used in sausage preparation. All the terpenes identified in the present study have been reported in black pepper, paprika, bay leaves, fenugreek, ginger, and turmeric. One previous study reported that terpenes from spices added during manufacturing comprised the main group of volatiles found in fermented sausages (Latorre et.al., 2011).

The present study shows that fermentation and cooking, which change the physical nature and composition of burgers and sausages, play an important role in the preparation of high-palatability products. Fermentation and cooking produce many volatiles, including organosulfur compounds, alkyl aldehydes, ketones, acids, esters, alcohols, and terpenes, some of which contribute characteristic flavors to the final meat products. Our results indicate that volatile chemicals formed by cooking and/or fermentation improve the palatability of meat products.

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