Hazelnut as functional food component and fat replacer in fermented sausage

Deray Saygi¹ · Hüdayi Ercoşkun² · Ekin Şahin³

Revised: 14 March 2018 / Accepted: 18 March 2018 / Published online: 11 July 2018
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Abstract It is intended to develop a fat substituted, low fat and functional fermented sausage by determining the effects of fat substitution (15, 30 and 45% ratio) with hazelnut paste in traditional fermented sucuks. The increase in fat substitution ratio increased the dry matter but decreased the fat and cholesterol content in hazelnut added sausages. Control samples cholesterol content were 89.47 ± 0.55 mg/100 g while 15, 30 and 45% hazelnut substituted samples were 87.33 ± 1.20 , 84.93 ± 0.61 and 82.28 ± 0.50 , respectively. Hazelnut added sucuks had lower cholesterol level and a functional fatty acid profile with a indexes of atherogenicity and thrombogenicity. However hazelnut added sucuks had increased TBARS values. The sensory properties of sucuk did not adversely affect by replacement of fat with hazelnut.

Keywords Sucuk · Hazelnut · Fat substitution · Fatty acids · Cholesterol · Colour · Texture · Sensory

Introduction

Consumer choices are pressurizing meat industry for low fat, healthier and as well as functional meat products (Ilkkan et al. 2009; Kılıç and Özer 2017; Jalarama Reddy et al. 2015). At first glance, fermented sausages are characterized both its high-fat level and its eminent saturated fatty acid profile or cholesterol level. Sucuk is one of popular fermented sausage in Turkey and culturally neighboring countries in Balkans, Caucasus, Middle East. Sucuk contain 20–25% fat rises up to 40% during fermentation and drying. Therefore there is an increasing request for a healthier sucuk (Kılıç and Özer 2017). Therefore, extensive researches have been performed on substituting animal fat and/or reduction of the fat contents to improve overall quality of many fermented sausages with fibers, proteins, carbohydrates, and plant oils from various origins (Muguerza et al. 2002; García et al. 2002; Ercoşkun 2014).

Hazelnut is a good candidate for functional food supplement as well as fat replacer. Its desirable chemical composition stems from triglyceride types, amounts and their positions, functional contents such as phenols, tocopherols and phytosterols, vitamins, minerals, amino acids, and dietary fibres. Hazelnut oil contains 79.05–83.16% monounsaturated fatty acids, 7.15–9.00% saturated and 8.47–15.66% polyunsaturated fatty acids (Özkal et al. 2005). Fraser et al. (1992) reported that people who consumed nuts five or more times a week had a 50% reduced risk of coronary heart disease relative to those who never consumed nuts. It was obviously declared by FDA before that scientific evidence suggests, but does not prove that eating 1.5 oz per day of most nuts, such as hazelnuts, as part of a diet low in saturated fat and cholesterol, may

✉ Hüdayi Ercoşkun
hercoskun@karatekin.edu.tr

¹ Department of Animal Science, Faculty of Agriculture, Ankara University, Ankara, Turkey

² Department of Food Engineering, Faculty of Engineering, Çankırı Karatekin University, Çankırı, Turkey

³ Department of Food Engineering, Faculty of Engineering, Ankara University, Ankara, Turkey

reduce the risk of heart disease” (Yurttas et al. 2000; FDA 2004; Alasalvar et al. 2006; Simsek and Aykut 2007).

Tocopherols, phytosterols and antioxidant phenolics contents of hazelnut are strengthening stability against oxidation, and also hazelnut has several health protective properties, which make hazelnut a good candidate of functional fat replacer in fermented sausage. Yıldız-Turp and Serdaroglu (2008) and Ilikkan et al. (2009) replaced animal fat with refined hazelnut oil however tocopherols, phytosterols and antioxidant phenolics are removed during refining processes of commercial hazelnut oil. On the other hand, emulsification is a necessary step in studies of animal fat substitution with refined vegetable oils of fermented meats (Kayaardi and Gök 2003; Yıldız-Turp and Serdaroglu 2008; Ilikkan et al. 2009) which may cause inadequate drying, binding and retention of oils (Kılıç and Özer 2017). When hazelnut is directly utilized in fermented sausage, no further emulsification step would be necessary without loss of desired bioactive molecules (Ercoskun and Demirci-Ercoskun 2010). Moreover, hazelnut contains carbohydrates, proteins, fibres and vegetable oil which have been used in previous studies on replacing animal fat. The targets of this article were to evolve a functional, low-fat fermented sausage and examine the effects of beef fat substitutes with nuts.

Materials and methods

Sucuk preparation

Since traditional sucuk is one of most popular fermented sausage, sucuk is selected as fermented sausage. The formulation and sucuk production is described in a previous paper (Ercoskun and Demirci-Ercoskun 2010). Hazelnut paste was used to replace beef fat in three formulation as 15, 6 and 9% of fat weight used in dough. Only beef fat used in control sausage dough (Table 1). Hazelnuts were grinded finely with a food processor to obtain a smooth mash. Each application was prepared to contain 10% total fat and 90% beef. Hazelnut mash added to the next three treatments 15, 30 and 45% of fat in sausage mixture by weight. Moreover, same amount of hypodermic fat was not added.

A laboratory scale stuffer was used to stuff sausage dough into 40 mm collagen casing (Arı Torna, İstanbul, Turkey). Sucuks were kept at 20 °C (Relative Humidity: 70%) for 8 h. Ripening started at 25 °C and 90% relative humidity. It was reduced 3% per every day till the 5th day of fermentation process. Besides, ripening chamber temperature was put down to 22 and 20 °C after second and 4th days, respectively. Temperature and relative humidity were fixed after the 5th day up to 15th day.

Chemical analysis

Analysis of pH, dry matter (%), total fat (%) and 2-thio-barbituric acid (TBA) were carried out in dough samples, 15 days ripened sucuks and 30, 60 and 90 days stored samples. Ripened sucuks were also determined with cholesterol, fatty acid, color and texture analysis. Sensorial panel was performed in 30th day. Chemical, physical and sensorial analyses were carried out with the methods described in previous article (Ercoskun and Demirci-Ercoskun 2010). Fatty acid distribution results were computed and amounts of saturated fatty acids (SFA), unsaturated fatty acids (UFA), polyunsaturated fatty acids (PUFA), total ω -6 fatty acids and total ω -3 fatty acids and indices of atherogenicity (IA) and thrombogenicity (IT) were calculated according to Ulbricht and Southgate (1991). All the analysis was carried out in sampling day for 0th and 15th days. Polyethylene bags were used in vacuum packing of sucuks which were stored at 4 °C until sampling at 30th, 60th and 90th days.

Statistical analysis

Statistical analyses are described in a previous paper (Ercoskun and Demirci-Ercoskun 2010).

Results and discussion

Fat substitution with hazelnut did not affect the pH of sucuks from production to the last of storage (Table 2). The pH values of all sucuks decreased significantly during fermentation time ($p < 0.05$). The pH of sucuks ranged from 5.73 to 5.87 in the beginning of fermentation and the final pH varied from 4.84 to 4.97 on the 15th day. Obtained results were consistent with Bozkurt and Erkmén (2002) research which explained sharp pH decrease during the ripening period due to the formation of lactic acid. The declining of pH during fermentation in sausage was reported to be necessary because direct effect on prevention of unwanted bacteria, formation of color and flavor of fermented sausages (Incze 1992).

Table 1 Formulation of sucuks (%)

	C	15% h	30% h	45% h
Lean beef (10% fat)	90	90	90	90
Animal fat	10	7	4	1
Hazelnut	0	3	6	9
Beef fat + hazelnut	10	10	10	10
Total beef fat	20	17	14	11
Fat replacement ration	0	15	30	45

Table 2 pH values, moisture and fat contents and TBARS values of sucuk samples during fermentation and storage

	Fermentation (days)		Storage (days)		
	0	15	30	60	90
pH					
C	5.87 ± 0.08	4.97 ± 0.06	4.95 ± 0.10	5.15 ± 0.10	5.42 ± 0.11
15% h	5.73 ± 0.06	4.94 ± 0.06	4.96 ± 0.08	5.09 ± 0.08	5.36 ± 0.10
30% h	5.81 ± 0.05	4.90 ± 0.04	4.92 ± 0.10	5.07 ± 0.10	5.31 ± 0.11
45% h	5.78 ± 0.03	4.84 ± 0.04	4.89 ± 0.10	5.03 ± 0.10	5.19 ± 0.11
Dry matter					
Hazelnut			–	–	–
(%)					
C	41.29 ± 0.28Aa	66.58 ± 0.27Ba			
15% h	41.93 ± 0.14Ab	67.50 ± 0.27Bb	–	–	–
30% h	42.29 ± 0.11Ac	68.22 ± 0.18Bc	–	–	–
45% h	43.19 ± 0.11Ad	69.59 ± 0.14Bd	–	–	–
Fat					
Hazelnut					
(%)					
C	21.55 ± 0.12Aa	34.72 ± 0.13Ba	–	–	–
15% h	20.43 ± 0.12Ab	32.88 ± 0.14Bb	–	–	–
30% h	19.49 ± 0.13Ac	31.46 ± 0.33Bc	–	–	–
45% h	18.54 ± 0.14Ad	29.89 ± 0.33Bd	–	–	–
TBARS					
C	0.50 ± 0.02Aa	1.63 ± 0.02Ba	1.91 ± 0.02Ca	1.93 ± 0.02Ca	2.07 ± 0.02Da
15% h	0.52 ± 0.03Aa	1.66 ± 0.02Bab	1.97 ± 0.01Ca	2.16 ± 0.02Db	2.18 ± 0.02Da
30% h	0.55 ± 0.02Aa	1.69 ± 0.02Bab	2.20 ± 0.04Cb	2.32 ± 0.02CDc	2.44 ± 0.03Db
45% h	0.57 ± 0.02Aa	1.77 ± 0.03Bb	2.48 ± 0.04Cc	2.53 ± 0.05Cd	2.55 ± 0.02Cb

C: control sample, 15% h: 3% hazelnut added sample (15% of beef fat replaced), 30% h: 6% hazelnut added sample (30% of beef fat replaced), 45% h: 9% hazelnut added sample (45% of beef fat replaced), A–D: Different letters in the same column indicate significant difference ($p < 0.05$); a–c: Different letters in the same row indicate significant difference ($p < 0.05$). TBARS: (mg malonaldehyde/kg)

Fat substitution with hazelnut in fermented sausage significantly increased the dry matter of sausage dough ($p < 0.05$) (Table 2). The lower moisture content of hazelnut added sausage was due to lower moisture content of hazelnut rather than fat added to sausage dough. The dry matter contents of all samples were increased significantly during fermentation time ($p < 0.05$).

Beef fat substitution with hazelnut flour caused significant decrease in fat content ($p < 0.05$) (Table 2). This was because of the lower fat content of hazelnut comparing to the fat tissue used in sucuk production. Several studies on fat substitution in fermented sausages reported decrement of fat level which is in line with the study (Kayaardi and Gök 2003; Yıldız-Turp and Serdaroğlu 2008; Ilıkkan et al. 2009).

It was observed that TBARS values were affected significantly ($p < 0.05$) by the ripening time and hazelnut addition (Table 2). TBARS formation (lipid oxidation) ratio was higher in the fermentation and ripening period than during the other periods. Statistical analysis

demonstrated that addition of hazelnut increased ($p < 0.05$) the TBARS values. The main handicap in substitution of animal-originated fat by vegetable-originated oils was rancidity, since vegetable oils contain more unstable fatty acids than animal fat (Kayaardi and Gök 2003). Severini et al. (2003) found higher TBA values in salami substituted with olive oil (5, 7.5 and 10%) than in the control formulation during the drying process. Bloukas et al. (1997) found confirming results. However, Yıldız-Turp and Serdaroğlu (2008) produced sucuk by substituting different amounts of beef fat with hazelnut oil and reported that no significant difference in TBARS values. Ilıkkan et al. (2009) produced sucuk by substituting beef fat with hazelnut oil and reported an increment of TBARS values in hazelnut added samples. On the other hand, substitution of beef fat with hazelnut significantly reduced the cholesterol amounts of the samples ($p < 0.05$). Control sucuks contained the highest cholesterol level. Yıldız-Turp and Serdaroğlu (2008) and Ilıkkan et al. (2009) observed cholesterol content regularly decreased as the percentage of

Table 3 Cholesterol contents and fatty acid composition (methyl esters of the total fatty acids) of sucuks

	C	15% h	30% h	45% h
Cholesterol (mg/100 g)	89.47 ± 0.55a	87.33 ± 1.20ab	84.93 ± 0.61bc	82.28 ± 0.50c
C10:0 capric	0.08 ± 0.01a	0.08 ± 0.01a	0.07 ± 0.01ab	0.06 ± 0.01b
C12:0 lauric	0.07 ± 0.01a	0.06 ± 0.01ab	0.05 ± 0.01bc	0.04 ± 0.01c
C14:0 myristic	2.46 ± 0.01a	2.24 ± 0.04b	1.91 ± 0.05c	1.71 ± 0.03d
C15:0 pentadecanoic	0.41 ± 0.01a	0.34 ± 0.01b	0.32 ± 0.01b	0.26 ± 0.01c
C16:0 palmitic	20.74 ± 0.11a	19.38 ± 0.09b	17.63 ± 0.06c	15.54 ± 0.10d
C17:0 margaric	1.07 ± 0.03a	0.96 ± 0.02ab	0.88 ± 0.02c	0.73 ± 0.03c
C18:0 stearic	18.01 ± 0.05a	16.44 ± 0.05b	14.73 ± 0.05c	12.63 ± 0.05d
C20:0 eicosanoic	0.20 ± 0.01a	0.18 ± 0.01ab	0.18 ± 0.01ab	0.16 ± 0.01b
ΣSFA	43.04 ± 0.20a	39.92 ± 0.30b	35.77 ± 0.07c	31.14 ± 0.17d
C14:1 tetradecenoic	0.51 ± 0.01a	0.46 ± 0.01b	0.44 ± 0.01b	0.36 ± 0.01c
C16:1 palmitoleic	2.72 ± 0.02a	2.48 ± 0.02b	2.23 ± 0.01c	1.90 ± 0.03d
C18:1 oleic	45.48 ± 0.01a	49.12 ± 0.05b	53.31 ± 0.02c	57.72 ± 0.01d
C20:1 cis-11 eicosanoic	0.63 ± 0.01a	0.61 ± 0.01a	0.54 ± 0.02b	0.49 ± 0.02b
ΣMUFA	49.34 ± 0.10a	52.67 ± 0.04b	56.52 ± 0.14c	60.47 ± 0.8d
C18:2ω-6 linoleic	3.86 ± 0.06a	4.48 ± 0.02b	5.15 ± 0.02c	5.88 ± 0.06d
C18:3ω-6 γ-linolenic	0.54 ± 0.01a	0.51 ± 0.01b	0.48 ± 0.01c	0.43 ± 0.01d
C18:3ω-3 α-linolenic	0.84 ± 0.03a	0.69 ± 0.03b	0.65 ± 0.02bc	0.56 ± 0.01c
C20:2ω-6 eicosadienoic	0.21 ± 0.01a	0.20 ± 0.01a	0.19 ± 0.01a	0.14 ± 0.01b
C20:3ω-6 eicosatrienoic	0.65 ± 0.02a	0.56 ± 0.03a	0.55 ± 0.02a	0.44 ± 0.01b
C20:4ω-6 arachidonic	0.20 ± 0.02	0.18 ± 0.02	0.17 ± 0.01	0.14 ± 0.01
C20:5ω-3 eicosapentaenoic	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
ΣPUFA	6.33 ± 0.10a	6.66 ± 0.11a	7.20 ± 0.05b	7.61 ± 0.08b
ΣUFA	55.67 ± 0.16a	59.33 ± 0.09b	63.72 ± 0.11c	68.08 ± 0.20d
SFA/UFA	0.77 ± 0.01a	0.67 ± 0.01b	0.56 ± 0.01c	0.46 ± 0.01d
IT	0.99 ± 0.01a	0.85 ± 0.01b	0.71 ± 0.01c	0.58 ± 0.01d
IA	53.75 ± 0.10a	56.49 ± 0.10b	59.63 ± 0.15c	63.04 ± 0.12d
Σω-6	5.46 ± 0.12a	5.94 ± 0.08b	6.53 ± 0.04c	7.03 ± 0.08d
Σω-3	0.87 ± 0.03a	0.72 ± 0.03b	0.67 ± 0.03bc	0.59 ± 0.06c
Σω-6/Σω-3	6.27 ± 0.30a	8.22 ± 0.21b	9.78 ± 0.38c	11.98 ± 0.27d
PUFA/SFA	0.15 ± 0.01a	0.17 ± 0.01b	0.20 ± 0.01c	0.24 ± 0.01d

SFA saturated fatty acids, MUFA monounsaturated fatty acids, PUFA polyunsaturated fatty acids, IT index of thrombogenicity ($IT = [C14:0 + C16:0 + C18:0]/[(0.5 \times \Sigma MUFA) + (0.5 \times n - 6) + (3 \times n - 3) + (n - 3/n - 6)]$); IA index of atherogenicity ($AI = [C12:0 + (4 \times C14:0) + C16:0]/[(\Sigma PUFA) + (\Sigma MUFA)]$). Different letters in the same row indicate significant difference ($p < 0.05$)

hazelnut oil increased in sucuks which fat substituted with hazelnut oil. The relationship between fat and cholesterol content in meat and meat products are thoroughly discussed and it is proved that lowering of fat content in meat products result in the reduction of the amount of the cholesterol (Chizzolini et al. 1999).

Sucuk samples containing different levels of hazelnut showed variation in fatty acid compositions (Table 3). As for the fatty acid distribution, significant decrements ($p < 0.05$) in lauric, myristic, pentadecanoic, palmitic, margaric, stearic, and arachidic fatty acids were monitored in hazelnut added sucuks compared with those in control. Conversely, significant ($p < 0.05$) reducing capric acid was

observed only with 30 and 45% substitution. Significant decrement ($p < 0.05$) of SFAs contents developed the functional value of sucuks. Significant decrements ($p < 0.05$) were also observed in all MUFAs, but only oleic acid was significantly increased ($p < 0.05$) in sucuks made with hazelnut. Total MUFAs levels were significantly increased in sucuks with hazelnut. Linoleic acid were significantly increased ($p < 0.05$) but significant decrements ($p < 0.05$) in all other PUFAs hazelnut added sucuks compared with those in Control. In addition, the increase in linoleic acid also significantly increased ($p < 0.05$) total PUFAs reflected by the amount of hazelnut added. Substituting beef fat with hazelnut significantly reduced

($p < 0.05$) SFAs levels and increased ($p < 0.05$) MUFAs and PUFAs levels in hazelnut added sucuks compared with those in Control. Substituting beef fat with hazelnut significantly increased PUFA/SFA ratio. Significant higher ($p < 0.05$) $\Sigma\omega-6/\Sigma\omega-3$ and PUFA/SFA ratios were observed in hazelnut added sucuks.

Index of atherogenicity (IA) explains the relationship between the sum of the main saturated and that of the main classes of unsaturated fatty acids while index of thrombogenicity (IT) is the relationship between the prothrombogenic (saturated) and the anti-thrombogenic fatty acids (MUFAs, PUFAs-n6 and PUFAsn3). In other words, low AI and TI values indicate that high quantities of anti-atherogenic fatty acids in foods which are preventing coronary diseases. The substitution of animal fat with hazelnut increased MUFA, PUFA, PUFA/SFA, UFA, $\omega-6$, $\omega-6/\omega-3$ and AI values but decreased SFA, SFA/UFA, IT and $\omega-3$ values. These changes in the amount of fatty acids

in hazelnut added samples resulted with a healthier fatty acid distribution except the decrease of $\omega-3$.

Changes in the profile of fatty acids distribution of sucuks with hazelnut are in agreement with sucuks containing hazelnut oil. Yıldız-Turp and Serdaroğlu (2008) reported that, replacement of 50% beef fat with 50% hazelnut oil significantly increased MUFA, PUFA and MUFA + PUFA/SFA values. İlkkan et al. (2009) reported that replacement of beef fat with hazelnut oil resulted with increment of oleic and linoleic acids in sucuk samples.

Control sausages showed the significantly higher values for chewiness. Chewiness values were decreased with increased walnut substitution ratio ($p < 0.05$) except 45% substituted samples (Table 4). Similarly, İlkkan et al. (2009) reported that hazelnut oil addition softened the sausage samples.

A significant effect was not observed over the L^* values due to assayed modifications. Yıldız-Turp and Serdaroğlu

Table 4 Instrumental texture and colour parameters of sucuks

	Control	15% h	30% h	45% h
Chewiness (Nxmm)	30.66 ± 3.36a	24.04 ± 4.45ab	21.78 ± 2.47b	22.25 ± 1.95ab
L^*	36.99 ± 1.51	34.90 ± 0.61	34.74 ± 1.01	34.92 ± 1.24
a^*	12.61 ± 0.98a	13.13 ± 0.37ab	11.40 ± 0.67ab	10.76 ± 0.41b
b^*	12.84 ± 0.94a	11.73 ± 0.90ab	10.51 ± 0.54ab	8.97 ± 0.32b

Different letters in the same row indicate significant difference ($p < 0.05$)

Fig. 1 Effect of replacing beef fat with hazelnut on some sensory properties of sucuks

(2008) reported that treatment with hazelnut oil increased L^* values of sucuk dough but not final product. Ilikkan et al. (2009) reported that addition of hazelnut oil to sucuk, resulted a lighter colour in final products. Bloukas et al. (1997) found that the control of dry fermented sausages was darker and less yellow than the products in which olive oil replaced pork backfat. Redness values significantly decreased as the hazelnut substitution ratio increased ($p < 0.05$) except 15% hazelnut added sample which may be caused because of dilution of myoglobin. Yıldız-Turp and Serdaroglu (2008) reported that hazelnut oil replacement increased the a^* values of the samples. Ilikkan et al. (2009) reported that hazelnut oil addition significantly affected a^* values and a^* value was between 10.33 and 13.38 in hazelnut added samples. The b^* values of the samples were decreased significantly by the fat replacement ($p < 0.05$).

The sensory scores for different samples are shown in Fig. 1. There were no significant differences in colour, consistency, appearance and taste and flavour characteristics between samples ($p > 0.05$), but sensory scores decreased as substitution ratio increased. Since fat contributed colour, texture and flavour to meat products, reducing fat content and/or substituting fat in formulation may alter sensory quality. All of the sucuk samples took scores were over acceptable level 5. Yıldız-Turp and Serdaroglu (2008) reported that incorporating hazelnut oil in the sucuk formulation decreased sensory scores of slice appearance, flavour and texture. Bloukas et al. (1997) found that olive oil added fermented sausages received the lower texture scores. They also concluded that the level of olive oil had no effect on odour and taste scores of fermented sausages. Similarly, the scores awarded by the assessors were very similar, independent of the animal fat substitution in this study.

Conclusion

It can be concluded that up to 45% substitution of beef fat which was used traditionally in the formulation of sucuk by hazelnut was feasible. This application improved the nutritional and biochemical properties in terms of cholesterol reduction and total monounsaturated and polyunsaturated fatty acids increment. Healthier the fatty acid distributions were observed in increased levels of hazelnut added samples with lower cholesterol levels. On the contrary, lipid oxidation was increased with increasing levels of hazelnut replacement ratio.

Acknowledgements This research was a part of Deray ALPAY's Master Thesis.

References

- Alasalvar C, Amaral JS, Shahidi F (2006) Functional lipid characteristics of Turkish tombul hazelnut (*Corylus avellana* L.). J Agric Food Chem 54:10177–10183
- Bloukas JG, Paneras ED, Fournitzis GC (1997) Effect of replacing pork backfat with olive oil on processing and quality characteristics of fermented sausages. Meat Sci 2:133–144
- Bozkurt H, Erkmen O (2002) Effects of starter cultures and additives on the quality of Turkish style sausage (sucuk). Meat Sci 61:149–156
- Chizzolini R, Zanardi E, Dorigoni V, Ghidini S (1999) Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci Technol 10:119–128
- Ercoskun H (2014) Effect of cheese as a fat replacer in fermented sausage. J Food Sci Technol 51(8):1588–1593
- Ercoskun H, Demirci-Ercoskun T (2010) Walnut as fat replacer and functional component in sucuk. J Food Qual 33(5):646–659
- FDA, US Food and Drug Administration (2004) Office of nutritional products. Labelling and dietary supplements. Qualified health claim: letter of enforcement discretion—walnuts and coronary heart disease. Docket no 02P-0292
- Fraser GE, Sabaté J, Beeson WL, Strahan TM (1992) A possible protective effect of nut consumption on risk of coronary heart disease. The Adventist Health Study. Arch Intern Med 152:1416–1424
- García ML, Dominguez R, Galvez MD, Casas C, Selgas MD (2002) Utilization of cereal and fruit fibers in low fat dry fermented sausages. Meat Sci 60:227–236
- Ilikkan H, Ercoskun H, Vural H, Şahin E (2009) The effect of addition of hazelnut oil on some quality characteristics of Turkish fermented sausage (sucuk). J Muscle Foods 20:117–127
- Incze K (1992) Raw fermented and dried meat products. Fleischwirtschaft 72(1):58–62
- Jalarama Reddy K, Jayathilakan K, Pandey MC (2015) Olive oil as functional component in meat and meat products: a review. J Food Sci Technol 52(11):6870–6878
- Kayaardi S, Gök V (2003) Effect of replacing beef fat with olive oil on quality characteristics of Turkish soudjouk (sucuk). Meat Sci 66:249–257
- Kılıç B, Özer CO (2017) Effects of replacement of beef fat with interesterified palm kernel oil on the quality characteristics of Turkish dry-fermented sausage. Meat Sci 131:18–24
- Muguerza E, Fista G, Ansorena D, Astiasaran I, Bloukas JG (2002) Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. Meat Sci 61:397–404
- Özkal SG, Salgın U, Yener ME (2005) Supercritical carbon dioxide extraction of hazelnut oil. J Food Eng 69(2):217–223
- Severini C, De Pilli T, Baiano A (2003) Partial substitution of pork backfat with extra-virgin olive oil in “salami” products: effects on chemical, physical and sensorial quality. Meat Sci 64(3):323–331
- Şimsek A, Aykut A (2007) Evaluation of the microelement profile of Turkish hazelnut (*Corylus avellana* L.) varieties for human nutrition and health. Int J Food Sci Nutr 58:677–688
- Ulbricht TLV, Southgate DAT (1991) Coronary hearth disease. 7. Dietary factors. Lancet 338(8773):985–992
- Yıldız-Turp G, Serdaroglu M (2008) Effect of replacing beef fat with hazelnut oil on quality characteristics of sucuk—a Turkish fermented sausage. Meat Sci 78:447–454
- Yurtas HC, Schaffer HW, Warthesen JJ (2000) Antioxidant activity of nontocopherol hazelnut (*Corylus* spp.) phenolics. J Food Sci 65:276–280