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Partial Substitution of Beef Fat with Hazelnut Oil in Emulsion Type Sausages: Effects on Chemical, Physical and Sensorial Quality

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Abstract: The effects of hazelnut oil on some properties of sausages have been studied. Beef fat was replaced by hazelnut oil at levels of 60 and 90%. Incorporation of hazelnut oil into sausages had no effect on emulsion properties but resulted softer texture. Cholesterol content decreased progressively as the percentage of hazelnut oil increased in the formulation. Replacement of beef fat with 60 and 90% hazelnut oil significantly increased MUFA, PUFA and MUFA + PUFA/SFA ratios. After 45 days of storage at 4°C, all sausage samples had TBA values within acceptable limits. Yellow colour in slice appearance was enhanced in samples with hazelnut oil. With regard to organoleptic characteristics panel evaluated sausages with hazelnut oil had softer texture. Results showed that up to 90% of beef fat can be replaced by hazelnut oil in the production of sausages but further research is needed to improve the texture of sausages.

Key words: Sausage, hazelnut oil, cholesterol, fatty acid composition, oxidation

INTRODUCTION

Consumers often associate meat with a negative image that meat contains high fat and red meat in particular is regarded as cancer-promoting (Ruusunen and Puolanne, 2005). This growing interest for health has led food industries worldwide to make big efforts in the development of novel products with improved functional properties, nutritional value and product stability. Fats in meat products plays an important role in stabilizing emulsion, reducing cooking loss increasing water holding capacity and improving juiciness and texture (Pietrasik and Duda, 2000).

Hughes *et al.* (1997) have also found that fat has considerable effects on the binding, rheological and structural properties of meat products. It is well known that high fat content in the diet provides high amounts of saturated fatty acids and cholesterol and causes obesity, hypertension, cardiovascular diseases and coronary heart diseases (Serrano *et al.*, 2007; Ozvural and Vural, 2008). Colmenero (2000) notes that the consumption of processed meat is closely linked to taste; low-fat meat products that are not acceptable in terms of palatability or appearance will not sell regardless of the health characteristics attributed to them. Excessive reduction of fats from meat products resulted in reduced cooked yields, soft and mushy interiors, rubbery skin, purging and shortened shelf life and changes in mouth-feel (Keeton, 1994). Besides maintaining sensory characteristics, the incorporation of vegetable oils instead of animal fats improves the nutritional composition of meat products. Hence, research to substitute animal fats with vegetable oils in various types of meat products has gained much attention in meat manufacturing industry. Up to this date, a variety of vegetable fats has been incorporated into different types of meat products such as frankfurters (Marquez *et al.*, 1989; Bishop *et al.*, 1993; Paneras and Bloukas, 1994; Ambrosiadis *et al.*, 1996; Jo *et al.*, 2000; Pappa *et al.*, 2000; Vural and Javidipour, 2002; Luruena-Martinez *et al.*, 2004; Vural *et al.*, 2004; Tan *et al.*, 2006; Ozvural and Vural, 2008; Valencia *et al.*, 2008; Koutsopoulos *et al.*, 2008; Lopez-Lopez *et al.*, 2009), hamburgers (Liu *et al.*, 1991), fermented sausages (Bloukas *et al.*, 1997; Muguerza *et al.*, 2001; Yildiz-Turp and Serdaroglu, 2008) and emulsified meatballs (Hsu and Yu, 2003).

Turkey produces about 550,000 tons of hazelnut annually which is approximately 80% of the world's hazelnut production (Demir *et al.*, 2003). Hazelnut is the most produced nut in Turkey. It has a high nutritional value containing generally, 65% oil, 14% protein and 16% carbohydrates. About >90% of its oil consists of unsaturated fatty acids, especially oleic (C18:1, 80%) and linoleic (C18:2, 12%) acids (Ozkal *et al.*, 2005). Currently, hazelnut oil is used mainly in salad dressings and cosmetic and pharmaceutical products (Xu *et al.*, 2007). The aim of this study was to evaluate the effects of partial substitution of beef fat with hazelnut oil on the sensory, chemical and physical characteristics of sausages.

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MATERIALS AND METHODS

Preparation of sausages: Fresh lean beef (moisture 75.8%, fat 9.7% and protein 17.5%) and beef fat were purchased from local processor. Hazelnut oil was obtained from a local market. All subcutaneous and intramuscular fat and visible connective tissue were removed, lean material was ground through a 3 mm plate. Three different sausage emulsions were prepared. In every formulation total added fat was 20%. The first one was the Control (C) and prepared with 20% beef fat for the other two formulations fat was replaced with hazelnut oil at a level of 60% (O 60) and 90% (O 90).

Fat was pre-emulsified with 1.6% salt, 3.6% soy protein, 2.1% sodium caseinate, 28.4% water in a cutter for 5 min. Ground meat, curing ingredients (2% salt, 0.5% sodium phosphate, 0.5% sodium ascorbate, 0.015% sodium nitrite and half the ice (10%) were homogenized and in a cutter for 2 min, then preemulsified fat (20%), spice mix (1.5%) binder and extender additives and other half the ice (10%) were added to the ground meat and homogenized for an additional 6 min. Batters were stuffed into synthetic casings using a hydraulic sausage filling machine (Alpina-SG-Schweiz) and smoked at 45°C for 105 min in smoking cabinet AFOS MINI KLN. The sausages were heat processed in steam jacket vessel at 80°C until reached 73°C internal temperature, afterward cooled in iced water for 15 min before being stored at 4°C overnight. After that the sausage samples were vacuum packaged.

Proximate analyses: Moisture content was determined according to AOAC (1990) procedures. Fat content was determined by chloroform-methanol extraction according to Flynn and Bramblett (1975) and protein content was determined according to Anonymous (1979).

pH: pH was measured directly using a probe type electrode according to Landvogt (1991).

Rancidity test: The 2-Thiobarbituric Acid (TBA) Test according to Tarladgis *et al.* (1960) as modified by Shahidi *et al.* (1985) was used to determine the extent of oxidative rancidity on the 0, 15, 30 and 45 days of storage.
Penetrometer values: Sur penetrometer (PNR 6, Berlin, Germany) equipped with a total 100 g load was used to evaluate samples for hardness. Depth puncture was determined to 1/10 mm in triplicate for each sample slice (2 cm). A lower depth of penetration indicates a harder texture.

Colour: Objective measurement of colour (L* lightness, a* redness, b* yellowness) was performed at the surface and the inside of the sausages using a Minolta 508-D spectrophotometer. Before each measurement the apparatus was standardized against a white plate. Samples were covered with a transparent film with pressure to obtain a uniform surface. There was no gap between the sample and the lenses of the spectrophotometer. Colour was measured on five randomly chosen spots of two sausages.

Processing yield: Processing yield was determined according to Bloukas *et al.* (1997). Sausages were weighed before heat processing and smoking and after chilling at 2°C overnight. The processing yield (%) was calculated on the basis of the weight of frankfurters before heat processing.

Jelly and fat separation: The jelly and fat separation was measured as described by Bloukas and Honikel (1992) and Luruena-Martinez *et al.* (2004). At the end of the comminution process three pre-weighed jars were filled with batter. The jars were closed and heated for 35 min in a boiling water bath. After cooling in running tap water the jars were stored at 4°C for 24 h. After warming up the cans in a water bath at 45°C for 1 h, the fluid in each jar was collected in a volumetric cylinder. The fluid jelly and fat, separated in the volumetric cylinder were measured and calculated as a percent of the original weight of batter. The mean value of three jars was taken for each treatment.

Purge loss: Purge accumulation was determined according to Bloukas *et al.* (1997). Three vacuum packages per treatment were used to determine purge accumulation of sausages. Before packaging each link of frankfurters was patted dry with paper towells and were weighed. After the storage at 4°C for 7 days, sausages were removed from the package again patted dry and reweighed. Purge accumulation was determined from the difference in weights between the two measurements expressed as a percentage of initial weight.

Cholesterol determination: Total cholesterol content of sausages was determined according to Naeemi *et al.* (1995). Samples were hydrolyzed with saturated methanolic KOH. Cyclohexane was added to the mixture and the upper layer was analyzed. Analyzes were performed using a gas chromatograph (HP 5890) fitted with a column (Ultra performance capillary column, cross

linked methyl silicone gum; 25 m ×0.32 mm ×0.52 μm film thickness, HP 5080-8853) under the following operating conditions; carrier gas, helium with a flow rate of 1.5 mL min^{-1}; oven temperature 180-280°C at 20°C min^{-1} hold at 280°C for 10 min; injector temperature 290°C; detector, flame ionization at 300°C. Cholesterol standard (Sigma C-8667) was used to determine the amount of cholesterol in the samples.

Fatty acid composition: Lipids were extracted from duplicate 10 g samples with chloroform:methanol (2:1, v/v) (Flynn and Bramblett, 1975) and methylated (Paquot and Hautfenne, 1987). Fatty Acid Methyl Esters (FAME) were analyzed using a gas chromotograph (HP 5890) fitted with a fused silica capillary column (CP-Sil-88; 50 m ×0.25 mm i.d., 0.20 μm film thickness of polyethylene glycol) (Chrompack Ltd., London, UK). The column temperature was programmed 100-220°C at 4°C/min and 15 min at 220°C. The injector temperature was 220°C and the detector (FID) temperature 220°C. The carrier gas was hydrogen at a flow rate of 1 mL min^{-1}. The fatty acids were identified by comparison of their retention times of the sample with those of standards.

Sensory evaluation: Samples from each formulation were randomly assigned for sensory evaluation. Sausages were served warm to a nine membered trained panel (graduate students and staff of Ege University Food Engineering Department). Selection of panel members was based on their particular interests in taste and flavour acuity and ability to understand the test procedures. Panel members were trained in two sessions during which they were served sausages from a wide variety of treatment to familiarize themselves with the properties to be evaluated. Sausages were cut approximately 2.5 cm thickness and boiled for 5 min. All samples were served as warm. Water and bread were served for cleaning the mouth between samples. At each session three sausage samples were served immediately to panelists and were subjected to sensory evaluation for appearance, colour, taste, texture, oiliness, oxidized flavour and overall acceptability. A five point scale was used where 1.0 corresponded to the lowest score and 5.0 the highest for colour, oiliness and oxidized flavour attributes. An eight point scale was used for the other attributes. For the texture attributes, 8 corresponded to the extremely hard and 1 corresponded to the extremely soft.

Statistical analyses: The data was analyzed by one way ANOVA using the SPSS Software Version 11 (SPSS, 2001). Differences among the means were compared using Duncan's multiple range test. A significance level of $p \leq 0.05$ was used for all evaluations.

RESULTS AND DISCUSSION

Chemical composition and pH values of sausage samples are shown in Table 1. No differences ($p>0.05$) were found in moisture, fat and protein contents and pH values between treatments. Marquez *et al.* (1989) observed no difference in proximate composition of frankfurters with 60% peanut oil. Final pH value of samples varied from 6.06-6.07. No significant differences were observed in pH values of samples. Similarly soy seed oil, sunflower oil, cotton seed oil, corn oil, palm oil (Ambrosiadis *et al.*, 1996), olive oil (Bloukas and Paneras, 1993) and sunflower oil (Yilmaz *et al.*, 2002) usage in sausage formulations were not found significantly affect the pH values of samples (Table 2).

Jelly and fat separation, processing yield, purge accumulation are indicative of hydration/binding properties which represents the ability of the meat emulsion to retain moisture and fat upon further processing. Pre emulsification of hazelnut oil with soy protein and caseinate improved the emulsion properties of sausages so no changes in emulsion properties of sausages with hazelnut oil were observed. Ambrosiadis *et al.* (1996) indicated that replacing pork back fat with soya, sunflower, cottonseed, corn oil or palmine at a level of 90% resulted higher emulsion stability in beef meat frankfurters (Table 3).

Usage of hazelnut oil in sausage formulation had no significant effect on jelly and fat separation ($p>0.05$). Similarly olive oil (Luruena-Martinez *et al.*, 2004) and sunflower oil (Ambrosiadis *et al.*, 1996) were not found significantly effective on jelly and fat separation of frankfurters. Incorporation of hazelnut oil to sausage formulation did not significantly affect the processing yield, purge loss of sausages and pH value of emulsion ($p>0.05$). Marquez *et al.* (1989), detected that incorporation of peanut oil that a level of 60% had no effect on the processing yield of the frankfurters according to the control samples.

Table 1: Usage rates of hazelnut oil in sausage production

Samples	Hazelnut oil (%)	Animal fat (%)
Control	-	100
H60	60	40
H90	90	10

Table 2: Proximate composition and pH value of sausage samples

Samples	Moisture (%)	Fat (%)	Protein (%)	pH
C	56.9	20.5	12.7	6.06
H60	56.8	19.2	13.3	6.07
H90	53.4	20.0	13.9	6.06

Table 3: Emulsion properties and pH value of sausage samples

Samples	Jelly and fat separation (%)	Processing yield (%)	Purge loss (%)	pH value of emulsion
C	3.4	91.7	1.2	6.04
H60	3.7	92.0	1.0	6.03
H90	3.5	92.2	1.3	5.99

However, Bloukas and Paneras (1993) found 5.5-6.5% lower processing yields for low-fat frankfurters than control samples. Choi *et al.* (2010), detected that the cooking yield was higher in frankfurters formulated with vegetable oil and rice bran fiber than in the control. The reasons of the differences in the results of processing yields of frankfurters from different researches could be the emulsion capacity and amount of oil used and additives that have emulsifier property in the formulations.

Bishop *et al.* (1993) determined that bologna containing emulsified oil had higher purge loss than that not containing oil. They stated that the higher purge of the bologna containing corn oil may have been due to oil being liquid at refrigerated temperatures which allowed it to migrate easier within the protein matrix if not completely emulsified. Choi *et al.* (2009) investigated the effects of vegetable oils prepared from olive, corn, soybean, canola or grape seed and rice bran fiber on the composition and rheological properties of emulsified meat batters and found that pH of meat batters were higher in batters formulated with vegetable oil and rice bran fiber than the control.

Table 4 shows the penetration values and colour properties of sausages. One of the most important problem adding vegetable oils into the meat products is the softening in the texture. The penetration values of sausages were ranged from 7.3-8.3 mm. The results showed that hazelnut oil incorporated sausages had the higher penetration values (softer texture) than control. Similar soft texture problem was observed by other researchers that used vegetable oils in emulsion type meat products (Bishop *et al.*, 1993; Ambrosiadis *et al.*, 1996; Vural and Javidipour, 2002; Yilmaz *et al.*, 2002; Luruena-Martinez *et al.*, 2004). Usage of hazelnut oil in sausage formulation slightly inreased surface and slice L* values of samples but that increment was not found statistically insignificant (Table 4).

Usage of sunflower oil in sausage and salami (Ambrosiadis *et al.*,1996), corn oil in sausages (Jo *et al.*, 2000), canola and canola-olive oil in frankfurters (Alvarez *et al.*, 2011) were determined that increased the L* value. But Bloukas and Paneras (1993) did not detect the difference between control and samples with olive oil for the L* and b* value.

Table 4: Effect of replacing beef fat with hazelnut oil on penetration value and colour parameters of the frankfurter samples

		Surface colour			Slice colour		
Samples	Penetration value (mm)	L*	A*	b*	L*	a*	b*
C	7.3^{a}	52.9	16.4	19.1	59.9	12.8	14.4^{a}
H60	8.2^{b}	54.9	15.7	20.3	63.8	12.0	16.2^{b}
H90	8.3^{b}	54.9	16.1	20.5	64.0	12.2	16.7^{b}

Means within same column with different letters (a, b) are significantly different ($p<0.05$)

Sausages made with hazelnut oil showed significantly ($p<0.05$) higher b* values on slice color than sausages made with beef fat ($p<0.05$). The yellow colour of the hazelnut oil is the reason of the determination of higher b* value in sausages that containing hazelnut oil. The reason of the unchanged colour of the outer surface of the sausages is the smoking and boiling processes that reduced the differences between the formulations. Ozvural and Vural (2008) found that the increase of hazelnut oil level from 33.3-84.6% in treatments with interesterified oil blends had no effect ($p>0.05$) on the redness of frankfurters while the same increase of interesterified cottonseed oil level reduced ($p<0.05$) the redness of frankfurters.

Table 5 shows the cholesterol content and fatty acid composition of the samples. Cholesterol content decreased progressively as the percentage of hazelnut oil used increased ($p<0.05$). H60 and H90 samples had significantly lower cholesterol contents than control samples. Similar results were found in sausages that incorporated peanut oil (Marquez *et al.*, 1989) and olive, grape seed, corn, canola and soybean oil (Choi *et al.*, 2010) in different amounts.

The addition of hazelnut oil altered the fatty acid composition of sausages significantly ($p<0.05$) (Table 5). Significant decreases in miristic (C14:0), pentadecanoic (C15:0), palmitic (C16:0), palmitoleic (C16:1), margaric (C17:0), stearic (C18:0) arachidic (C17:0) acid contents were observed in sausages containing hazelnut oil. However, oleic acid (C18:1) and linoleic acid (C18:2) content increased as the amount of hazelnut oil increased in the sausage formulation ($p<0.05$).

Table 5: Cholesterol content and fatty acid composition of sausages

	Samples		
Cholesterol (mg/100 g)	C (26.5^{b})	H60 (16.3^{a})	H90 (13.2^{a})
Fatty acid composition (%)			
C10:0	0.3	0.1	-
C12:0	0.2	0.1	-
C14:0	4.3^{c}	1.7^{b}	0.9^{a}
C14:1	0.6	0.3	0.2
C15:0	0.8^{c}	0.3^{b}	0.1^{a}
C16:0	26.8^{c}	15.7^{b}	11.6^{a}
C16:1	2.5^{c}	1.5^{b}	1.0^{a}
C17:0	1.5^{c}	0.6^{b}	0.3^{a}
C17:1	0.7^{b}	0.3^{a}	0.2^{a}
C18:0	22.5^{c}	10.7^{b}	6.8^{a}
C18:1	33.4^{a}	56.2^{b}	65.6^{c}
C18:2	4.6^{a}	11.5^{b}	12.7^{b}
C18:3	0.9	0.6	0.2
C20:0	1.3^{c}	0.4^{b}	0.3^{a}
∑SFA	57.4^{c}	29.7^{b}	20.0^{a}
∑MUFA	37.2^{a}	58.2^{b}	66.9^{c}
∑PUFA	5.4^{a}	12.1^{b}	13.0^{b}
MUFA+PUFA	42.6^{b}	70.3^{b}	80.0^{c}
MUFA+PUFA/SFA	0.7^{a}	2.4^{b}	4.0^{c}

Means within same column with different letters (a-c) are significantly different ($p<0.05$)

PUFAs are also known to reduce plasma cholesterol level furthermore there are reports of other potential benefits such as reducing blood pressure and preventing cardiac arrhythmias (Abraham *et al*., 1989). Replacement of beef fat with 30 and 50% hazelnut oil significantly increased MUFA, PUFA and MUFA + PUFA/SFA ratios (Table 5). Total PUFA level was 5.4% in control samples, 12.1% in H60 samples and 13% in H90 samples. Saturated fatty acids significantly decreased with the increasing amount of hazelnut oil ($p<0.05$). Decrease in the SFAs fraction was due to oleic and linoleic acids which are abundant in hazelnut oil. Xu *et al*. (2007) found that oleic and linoleic acids comprised >90% of fatty acids in the hybrid hazelnut oil.

Significant increment in the MUFA+PUFA/SFA ratio due to increasing level of hazelnut oil indicated an improvement in nutritional content of sausages. The ratios of UFA+PUFA/SFA amounted were 0.7, 2.4 and 4.0, respectively for treatments with control, H60 and H90. According to the used oil type, different fatty acid profile modifications in meat products were observed. Valencia *et al*. (2008) found that addition of linseed oil to pork sausages increased the level of α-linolenic acid from approximately 1.34-8.91% and the addition of fish oil increased the long chain n-3 PUFA's EPA and DHA, characteristic of this oil type. Ozvural and Vural (2008), determined that increasing the interesterified hazelnut and cottonseed oil from 33.3-83.4% affected the fatty acid formulation of frankfurters thus oleic acid content increased gradationally due to the level of hazelnut oil and in the same way linoleic acid content increased with respect to the cottonseed oil ratio.

With regard to appearance, colour, juiciness, oiliness flavour, oxidized flavour and overall acceptance organoleptic characteristics there were no significant difference between the samples containing hazelnut oil and control. But the hardness characteristic of H60 samples was found significantly different from control samples by panelists (Table 6).

It can be concluded that in sausages, replacing beef fat with hazelnut oil up to 90% resulted acceptable sensory characteristics. Similarly, flavour and overall acceptance scores of bolognas that used corn oil (Bishop *et al*., 1993) and flavour, juiciness, colour, texture and overall acceptance scores of sausages that used peanut oil (Marquez *et al*., 1989) and overall acceptance scores of frankfurters that used olive oil (Luruena-Martinez *et al*., 2004) were recorded not significantly different from control samples. However, Pappa *et al*. (2000) have found a negative correlation between the level of olive oil and the overall acceptability of frankfurters produced by pork back fat. They determined that the low fat frankfurters with 0-35% olive oil had the highest overall acceptability.

One of the potential problems derived from using plant or seed oils in meat products could be an acceleration of the oxidative processes due to the increment in unsaturated fatty acids, particularly polyunsaturated ones which are more prone to oxidation. TBA values of sausages were between 0.40-0.44 mg ma kg^{-1} at the beginning of storage (Fig. 1). All sausage samples had TBA values within acceptable limits (<1.0) (Ockerman, 1976) during storage. The overall low TBA values indicate that lipid oxidation was not a problem in any of the treatments. The explanation for this could be the antioxidant activity of the α-tocopherol present in the added hazelnut oil. There were no significant difference in TBA values of sample groups during storage at 4°C for 45 days ($p>0.05$). But at the end of the storage period, all of the sample group's TBA value were found significantly different from eachother. At day 45, TBA values amounted were 0.23, 0.37, 0.45 mg ma kg^{-1}, respectively for treatments control, H60 and H90 and were found significantly different ($p<0.05$). Similar results were recorded for usage of corn oil (Bishop *et al*., 1993) and for olive oil (Bloukas and Paneras,1993; Paneras and Bloukas, 1994; Bloukas *et al*., 1997) in sausage samples. Choi *et al*. (2010) determined the highest TBA value in frankfurters with soybean oil and rice bran fiber. However, Hsu and Yu (2002) determined that all plant oil products had lower TBA values than the 10% fat control. Alvarez *et al*. (2011) concluded that the use of canola and olive oils did not produce significant changes of lipid oxidation levels in comparison with regular frankfurters. The probable reasons of different oxidation values in researches about usage of vegetable oils in sausages are the amount and fatty acid composition of vegetable oils used in formulations, effect of other additives with antioxidant properties and cooking process contidions. After 30 days of storage, TBA values had decreased in all formulations. The combination of aldehydes with other compounds and the loss of volatile aldehydes explain this behavior (Severini *et al*., 2003).

Table 6: Sensory properties of sausages

Samples	Appearance	Colour	Juiciness	Hardness	Oiliness	Flavour	Oxidized flavour intensity	Overall acceptance
C	6.6	4.5	5.5	6.4[b]	2.8	6.1	1.5	5.2
H60	6.4	3.2	5.9	4.4[a]	3.4	5.5	1.5	5.7
H90	5.3	3.2	5.7	4.7[ab]	3.4	5.1	1.7	5.1

Means within same column with different letters (a, b) are significantly different ($p<0.05$)

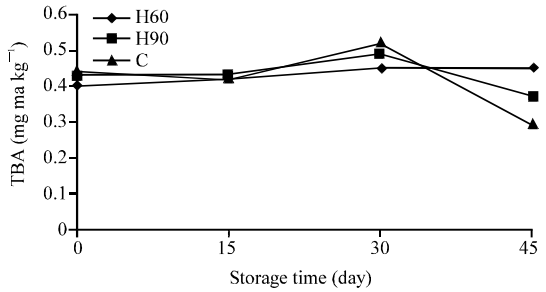

Fig. 1: Effect of replacing beef fat with hazelnut oil on TBA value in sausage samples

CONCLUSION

It is concluded that up to 90% of beef fat can be replaced by hazelnut oil in the production of sausages. The hazelnut replacement improved nutritional quality; lowered cholesterol and increased PUFA content without adversely affected the emulsification and sensory properties. Also oxidative quality of sausages was not negatively affected from using hazelnut oil during storage at 4°C for 45 days. In spite of usage of hazelnut oil caused softer texture and increament in yellow colour of sausage slices, overall acceptance scores were not significantly different from the control samples. So, the results suggest that up to 90% hazelnut oil may be successfully applied as beef fat substitute in sausage so, this kind of sausage could be a valuable option as healthy meat product, especially regarding that cholesterol and fatty acid composition.

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