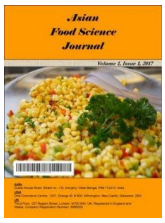

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Effect of Selected Oils on Antioxidant and Physicochemical Properties of Breakfast Sausage

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Authors' contributions

This work was carried out in collaboration among all authors. Author DOO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AIA, KAG, AKA and MAA managed the analysis of the study and read through the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The process of degradation converts fatty acid esters of oils into free fatty acids, by reaction with air, moisture and/or other materials. The main cause of rancidity of lipids is the oxidative deterioration of unsaturated fatty acids through a free-radical chain mechanism called lipid peroxidation. The aim of this study seek to evaluate the effect of selected oils on antioxidant and physicochemical properties of breakfast sausage.
Methodology: Breakfast sausage was prepared (g/100 g: beef 65.0, corn flour 10.0, oil 10.0, others 13.0). Lard, was replaced with shea butter, olive oil or groundnut oil in a completely

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randomized design. Prepared sausages were subjected to iodine values, acid values, saponification values, physicochemical evaluation and oxidative rancidity. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05.}$

Results: The iodine value was higher in olive oil-based sausages and lowest in lard-based sausages. The acid value was significantly higher in lard-based sausages, having the highest acid value of with least value in no oil-based sausage. The saponification values were higher in the groundnut oil-based breakfast sausage while the least saponification value was recorded in treatment A. Groundnut oil-based breakfast sausage had the highest dimensional shrinkage of 18.52% while olive oil-based breakfast sausages had the least dimensional shrinkage of 8.53%. Breakfast sausages prepared with groundnut oil had the highest cooking loss of 33.22% while the breakfast sausages prepared with olive oil had the lowest cooking loss of 15.69%. The result obtained from this study shows that no oil-based sausages had the highest pH (6.26) while olive oil based sausage had the lowest pH (6.09). The oxidative rancidity was higher in lard-based sausage but lower in olive oil-based sausage.

Conclusion: Lard can be replaced in breakfast sausages with olive oil due to its high antioxidant and physicochemical properties.

Keywords: Lard; olive oil; shea butter; groundnut oil; antioxidant properties.

1. INTRODUCTION

Consumers' perception of processed meat products are critical issues for the meat industry [1]. In recent years, consumers are increasingly conscious about healthy diet. However, most of the processed meat products contained high amounts of fat, which are related to chronic diseases such as obesity and cardiovascular heart diseases. Health organizations had suggested that intake of total dietary fat should be reduced, particularly saturated fatty acids and cholesterol, in order to prevent cardiovascular heart disease and other related diseases. Consumers now desired for low or reduced animal fat products with high palatability and nutritional quality [2].

Therefore, demand for healthier meat and meat products with reduced levels of salt, fat and improved fatty acid profile has increased globally. Breakfast sausage containing less salt and animal fat helps in reducing human dietary salt and cholesterol intake, thereby promoting health and wellness [3].

According to Chung et al. [4] who stated that, the economic development, quality of life, improvement and increasing concern about the health of modern life, the palatability and functionality of food are receiving attention as well as the ability to sustain life, and meat and meat products are becoming to the high-quality livestock product with intake convenience and a lot of functional materials in addition to the existing images of common protein foods [5]. In order to produce meat products with the functionality and safety, the needs for the environment-friendly natural preservatives and food additives with superior cell function regulating effect [6,7] are important.

The reduction or replacement of animal fat in meat products could be accomplished by changing the formulation by using plant-based oils i.e. using olive oils, groundnut oils and shea butter to replace lard.

The aim of this study therefore seek to evaluate the effect of selected oils on antioxidant and physicochemical properties of breakfast sausages.

2. MATERIALS AND METHODS

2.1 Meat Source and Sausage Preparation

Semi-membranous muscle from mature bull was purchased from the Jos abattoir. The meat was cleaned; connective tissue and fats were trimmed to produce lean meat. The meat was kept in the refrigerator at 4 ±1ºC, in order to reduce the microbial load, and for safety purposes. Meat and fat were prepared separately through an automated meat mincer. The meat was prepared through 6 mm plate and the fat through 4mm plate. The rest of the meat and the other ingredients were then thoroughly mixed and re-grand through a 4mm plate as shown in Tables 1 to 3. The prepared sausage were stuffed into presoaked natural casing (pig intestine) that was presoaked in brine using an automated stuffer. Sausage was subjected to grilling at 80ºC until internal temperature of 72ºC was reached to get the exact cooking time.

Table 1. Composition of sausages [1]

Ingredients (%)	A	B	C	D	E
Beef	65.00	65.00	65.00	65.00	65.00
Lard	10.00	_	_	_	_
Shear butter	_	10.00	_	_	_
Olive oil	_	_	10.00	_	_
Groundnut oil	_	_	_	10.00	_
Corn flour	10.00	10.00	10.00	10.00	10.00
Curing salt	2.00	2.00	2.00	2.00	2.00
Sugar	1.00	1.00	1.00	1.00	1.00
Binder (soya bean)	3.50	3.50	3.50	3.50	3.50
Phosphate	0.30	0.30	0.30	0.30	0.30
Ice water	4.00	4.00	4.00	4.00	4.00
Dry spices	2.00	2.00	2.00	2.00	2.00
Green spices	2.20	2.20	2.20	2.20	2.20
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

A= Sausage with lard, B=Sausage with shea butter, C= Sausage with olive oil, D= Sausage with groundnut oil, E= Sausage with no oil

Table 2. Composition of dry spices for breakfast sausages [1]

Spices	Inclusion level %
Black pepper	20.00
Nutmeg	7.00
Calabash nutmeg	3.00
Red pepper	20.00
Monosodium glutamate	15.00
Thyme	20.00
Curry powder	10.00
Total	**100.00**

Table 3. Composition of green spices for breakfast sausage [1]

Spices	Inclusion level %
Onion (*Allium cepa*)	60
Ginger (*Zingiber officinale)*	20
Garlic (*Allium sativum*)	20
Total	**100**

Source: [1]

2.2 Determination of Iodine Values

The iodine value of a substance is the weight of halogens expressed as iodine absorbed by 100 parts by weight of the substance. It was determined for each sample by measuring 1 g of the sample (m) into a 250 mL conical flask. About 15 mL of chloroform was added and 25mL of Iodine bromide was poured gently into the flask. The content in the flask was shaken and covered then left in a dark cupboard for 30 mins. About 10 mL of a 100 g/L solution of potassium iodide was added after 30mins and titrated with 0.1M sodium thiosulphate, shaking vigorously until the yellow colour is almost discharged. Further 5 mL of starch solution was added and then titration continued till the purple black colour from starch addition is completely discharged (n_1). A blank test was also carried out under the same condition (n_2) and the iodine value was calculated using the following formula:

$$IV = \frac{1.269\ (n_2 - n_1)}{m}$$

2.3 Determination of Acid Values

The acid value (*AV) is* the number that expresses, in milligrams the quantity of potassium hydroxide required to neutralise the free acids present in 1g of the substance. The acid value is often a good measure of the breakdown of the triacylglycerol into free fatty acids, which has an adverse effect on the quality of many lipids. About 5 g (w) of the samples were weighed into conical flask that is well labelled. Approximately 25 mL of equal volumes of ethanol and petroleum ether were poured into each conical flasks. One mililiters of phenolphthalein was added and titrated with 0.1 M of Potassium hydroxide until a stable pink colour (for 15 secs) was attained. The acid value was calculated by using the following formula:

$$\text{Acid value} = (5.6)\ \frac{n}{w}$$

2.4 Determination of Saponification Value

About 2 mL of the oil sample was added to 20 mL of Ethanolic potassium hydroxide in 500 mL round bottom flask. The flask with its content was

refluxed for 30 minutes. Further 2 ml of phenolphthalein indicator was added and the hot solution was allowed to cool and later titrated against 0.5 M hydrochloric acid.

2.4.1 Procedure

1. Approximately 2 g of the fat or oil was weighed into a 250mL conical flask.
2. 25 mL of alcoholic potassium hydroxide solution (0.5 N) was added .
3. A reflux condenser was attached and heated with the flask contents on a boiling water bath for 1 hour with occasional shaking.
4. 3 drops of phenolphthalein indicator was added to the hot solution. Excess potassium hydroxide was titrated with the 0.5 N hydrochloric acid (VmL of hydrochloric acid at end point represents S).
5. The above procedure but without sample was done for blank (VmL of hydrochloric acid at end point represents B).
6. Saponification value was calculated using the formula below:

$$\text{Saponification value: } \frac{56.1\ (B - S)\ X\ N \text{ of HCl}}{\text{Gram of sample used}}$$

Where:

B: mL of HCl required by Blank.
S: mL of HCl required by Sample

2.5 Cooking Loss

Cooking loss was determined according to the procedure described by [8].

2.6 pH

The pH was determined by using a digital pH meter model PHS- 25 Microfield instrument England according to the method described by [9]. The pH value of cooked sausage samples was determined by weighing 10g of sample into a blender with 90mL of distilled water and homogenised until smooth slurry was formed. The digital pH meter was placed in a buffer solution in order to allow equilibrium for two minute before placing it into prepared slurry. An average of three readings taken gave the pH value.

2.7 Analysis of Oxidative Rancidity

Thiobarbituric acid value (TBA) was estimated by modified methods of [10]. It measures the lipid peroxidation or rancidity. Three mls each of glacial acid and 1% TBA solution were added to test tubes appropriately labelled blank and tests. 0.6ml of distilled water was added to the blank, while 0.6ml of the homogenised sample was added to each of the tests tubes. These were thoroughly mixed, incubated in a boiling water bath for 15 minutes, then allowed to cool, after which they were centrifuged and their supernatants collected. The supernatant from the blank was used to zero the spectrophotometer (preset at 532nm) before reading the absorbance of the supernatant from the test solutions.

The amount of TBARS was expressed as milligrams of malondialdehyde per gram of sample.

$$\text{TBA} = \frac{\text{O.D x Vx1000}}{\text{A x v x l x Y}}$$

Where:

O.D = Absorbance of test at 532nm.
V= Total volume of the reaction mixture = 6.6mL
A= Molar extinction coefficient of the product, and according Buege and Aust (1978) is equal to $1.56x10^5$
l= Length of light path =1cm.
Y= mg of tissue in the volume of the sample used.
v= volume of tissue extract used =0.6ml

2.8 Statistical Analysis

Data were subjected to analysis of variance using SAS [11]. Means were separated using Duncan's Multiple Range Test option of the same software.

3. RESULTS AND DISCUSSION

3.1 Oxidative Properties of Breakfast Sausage

The iodine value was higher in olive oil-based sausage while the value in lard-based sausage was the least. Because melting point and oxidative stability are related to the degree of unsaturation, iodine value provides an estimation of these quality factors. The greater the iodine value, the more the unsaturation and the higher the susceptibility to oxidation. In Table 4, it was observed that there were significant differences in the iodine value of sausages made with different oil types. Olive oil based sausages were significantly different in iodine value when compared with other treatments.This could be

due to higher levels of unsaturated fatty acids present in olive oil compared to others.

The acid value indicates the amount of carboxylic acid group in a chemical compound such as fatty acid or in a mixture of compounds. The higher the acid value, the higher the rancidity level because as oil and fat become rancid; triglyceride are converted into fatty and glycerol. The acid value of the five treatments were statistically significant from each other, with treatment A, having the highest acid value of (17.28 mg/KOH/g of oil), treatment B (15.03 mg/KOH/g of oil), C (11.78 mg/KOH/g of oil) and E (8.63 mg/KOH/g of oil) had the lowest acid value. Lard based sausage had the highest acid value of 17.28 mg/KOH/g of oil, with least value in no oil based sausage (8.63 mg/KOH/g of oil). This could be due to the higher amount of saturation of oil in lard.

The saponification values were statistically significant from each other. Treatment D had the highest saponification value (271.38 mg/KOH/g of oil) while the least saponification value was in treatment A (126.23 mg/KOH/g of oil). Treatments B, C and E had saponification values of 231.41, 198.45 and 176.72 mg/KOH/g of oil respectively. It was also observed that the saponification value of the selected oils used for breakfast sausage were statistically different from each other. Olive oil had the highest saponification value (271.38 mg/KOH/g of oil) while lard based sausage had the lowest saponification value (126.23 mg/KOH/g of oil). This could be due to the higher unsaturated fatty acids present in olive oil compared to other oils.

3.2 Physicochemical Properties of Breakfast Sausages

Breakfast sausages prepared from groundnut oil had the highest dimensional shrinkage of 18.52% while breakfast sausages prepared from olive oil had the least dimensional shrinkage of 8.53%. Dimensional shrinkage is as a result of cooking process, due to the denaturation of the meat proteins with loss of water and fat. In this study, dimensional shrinkage ranges from 8.53% to 18.52% (Table 5). Olive oil based sausage had the least dimensional shrinkage which could had been due the ability of olive oil to bound properly with water to form better emulsion stability compared to other vegetable oil based sausage. Breakfast sausages prepared from groundnut oil had the highest cooking loss of 33.22% while the breakfast sausages prepared from olive oil had the lowest cooking loss of 15.69%. Breakfast sausages prepared from olive oil had the highest cooking yield of 84.31% while breakfast sausages prepared from groundnut oil had the least cooking yield of 66.78%. Breakfast sausages prepared from shea butter and groundnut oil are also not significantly different in their pH value. Cooking loss measures the water binding capacity of sausage which was affected by moisture, protein and fat content as well as processing methods. Cooking loss is an important factor because it is responsible for the appearance and juiciness of meat products [12]. Cooking loss in this study ranges from 15.69 to 33.22% (Table 5). Olive oil based sausage had the least cooking loss which could be due to the high cooking yield and ability to bound with water for emulsion stability.

Cooking yield connote the changes in weight due to moisture loss, water absorption or fat gains/ losses during food preparation. The cooking yield of sausage depends on the cooking temperature [13] cooking time [14], ingredients [15] and the amount of the fat in the products. The effect of selected oils on cooking yield of breakfast sausage in this study ranges from 66.78 to 84.31%. The highest value was observed in olive oil based sausage which could be due to the level of reduction in cooking loss and dimensional shrinkage. This observation was previously reported for various frankfurters [15, 16,17] patties [18,19] and meatball [20] noted that reducing the animal fat content in meat products by replacement with vegetable oil reduced cooking loss. The study by [16] demonstrated that processing yield was affected by locust bean/xanthan gum replacement. Another study by [21] reported that frankfurters containing rice bran fiber had significantly lower cooking loss than samples with no added fiber. Meat products appear to have improved water holding capacity and emulsion stability due to added dietary fiber and vegetable oil which leads to a higher cooking yield.

The pH of breakfast sausages as affected by selected vegetable oil was carried out to determine the acidity or alkalinity. The pH values greater than 7 are alkaline while pH values less than 7 are said to be acidic. The result showed that no oil based sausages had the highest pH (6.26) as shown in Table 5 while olive oil based sausage had the lowest pH (6.09). This could be due to high concentration of free fatty acid present in the oil based sausage.

Table 4. Effect of selected oils on oxidative properties of breakfast sausage

Parameter	A	B	C	D	E	SEM
Iodine value (mg iodine/100 g of oil)	0.95^{d}	0.32^{e}	7.93^{a}	7.30^{c}	7.62^{b}	0.92
Acid value (mg/KOH/g of oil)	23.23^{a}	15.03^{c}	11.78^{d}	17.28^{b}	8.63^{e}	1.33
Saponification value (mg/KOH/g of oil)	126.23^{e}	231.41^{b}	198.45^{c}	271.38^{a}	176.72^{d}	13.13

^{abc} Means on the same row with different superscripts are significantly different (p<0.05)
A= Sausage with lard, B=Sausage with shea butter, C= Sausage with olive oil, D= Sausage with grountnut oil, E= Sausage with no oil
SEM= Standard Error mean

Table 5. Effect of selected oils on physical properties of breakfast sausages

	A	B	C	D	E	SEM
Dimensional shrinkage%	11.34^{c}	10.27^{d}	8.53^{e}	18.52^{a}	12.92^{b}	0.91
Cooking loss %	20.30^{c}	22.95^{b}	15.69^{e}	33.22^{a}	15.96^{d}	1.71
Cooking Yield %	79.79^{c}	77.05^{d}	84.31^{a}	66.78^{e}	84.04^{b}	1.71
pH	6.09^{c}	6.13^{b}	6.09^{c}	6.11^{b}	6.26^{a}	0.02

^{abc} Means on the same row with different superscripts are significantly different (p<0.05)
A= Sausage with lard, B=Sausage with shea butter, C= Sausage with olive oil, D= Sausage with groundnut oil, E= Sausage with no oil
SEM= Standard Error mean

3.3 Oxidative Rancidity Properties of Breakfast Sausages

Oxidative rancidity properties of breakfast sausages as affected by different vegetable oil as lard replacer is represented in Fig. 1. The oxidative rancidity score of breakfast sausages was higher (P<0.05) in treatment D followed by treatment B with least score in treatment C.The oxidative rancidity properties of oil based breakfast sausage denote how susceptible a produce is to lipid oxidation which determines amount of microbial loads and spoilage. The oxidative rancidity of olive oil based breakfast sausages had least value compared to other oil based sausages as shown Fig. 1. This could be due to the amount of unsaturated fatty acid (mono unsaturated fatty acid and polyunsaturated fatty acid) present in olive oil. Oxidative rancidity values were higher for samples obtained with vegetable oil pre-emulsion, almost double with respect to control samples. Similar results were communicated by other researches too [21,22], which only confirms the higher vulnerability to oxidation of unsaturated fatty acids in vegetable oils. For low fat frankfurters, [22] reported oxidative rancidity values significantly higher for all samples with vegetable oil in comparison to control samples with no added vegetable oils. These results were in agreement with [23] who found that among those in which pork back fat was substituted with various vegetable oils, low-fat frankfurters with olive oil had the lowest TBA values, while those with soybean oil had the highest due to their free fatty acid composition. [24] described the effects of replacing pork back fat with olive oil on the processing and quality characteristics of sausages. Olive oil increased TBA values compared with the control, and those containing higher amounts of olive oil had higher TBA values. [25,26] demonstrated that replacing beef fat with olive oil and hazelnut oil improved the quality characteristics of fermented sausages.

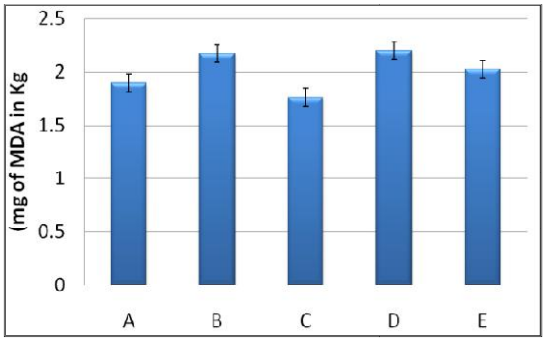

Fig. 1. Effect of oil on oxidative rancidity of breakfast sausage
A= Sausage with lard, B=Sausage with shea butter, C= Sausage with olive oil, D= Sausage with groundnut oil, E= Sausage with no oil

4. CONCLUSIONS

It can be concluded from the study that the lard can be replaced in breakfast sausages with olive oil due to its high antioxidant and

physicochemical properties. The reason for the resistance of olive oil to rapid deterioration at elevated temperatures is its fatty acid composition and the presence of natural antioxidants, such as tocopherols, squalene and Δ5-avenasterol. The polar antioxidants found in olive oil may also make a contribution to the increased stability to thermal oxidation and polymerisation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Oshibanjo DO. Yield and quality characteristics of breakfast sausage prepared with different dietary flours, salts and oils. A PhD thesis submitted to the Department of Animal Science, University of Ibadan; 2017.
2. Pietrasik Z, Duda Z. Effect of fat content and soy protein/carrageenan mix on the quality characteristics of comminuted, scalded sausages. Meat Sci. 2000;56(2): 181-8.
3. Olusegun D. Oshibanjo, Oyedapo Folasade, Odion Ikhimiukor. Effect of partial, combined and total replacement of sodium chloride in beef sausage on microbial load, sensory acceptability and physical properties. International Journal of Research and Innovation in Applied Science (IJRIAS). 2019;IV(IV):61-67.
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4. Chung M, Jung E, Joo N. (Kkuaripepper (*Capsicum annum* L.) and olive oil Effects on quality characteristics of pork sausage studied by response surface Methodology. J Exp Food Chem. 2016;2:114.
DOI:10.4172/2472-0542.1000114
5. Choe HJ, Lee BD, Liu XD, Song HP, Ho C. Antioxidant and antimicrobial effects of medicinal herb extract mix in pork patties during cold storage. Korean J Food Sci Ani Resour. 2008;28:122-129.
6. Park UY, Jang DS, Cho HR. Antimicrobial effect of lithospermiradix (Lithospermum erythrorhizon) extract. J Korean Soc Food Sci Nutr. 1992;21:97-100.
7. Lee JH, Ryu HS, Chung KS, Posé D, Kim S. Regulation of temperature-responsive flowering by MADS-box transcription factor repressors. Science. 2013;342:628-632.
8. Mahendrakar NS, Khabade US, Dam NP. Studies on the effect of fatting on carcass characteristics and quality of meat from Bannur lambs. J. Food Sci. Tech. 1988;25: 225-231.
9. AOAC Association of Official Analytical Chemistry Official Methods of Analysis of AOAC international (17th Ed.). MD, USA; 1990.
10. Buege JA, Aust SD. (Microsomal lipid, Peroxidation. In: Flesicher S, Packer L. (Eds.), Methods in Enzymology. Academic Press, New-York.1958;52:302–310.
11. SAS. SAS User's Guide: Basic statistical analysis. Cary, NC, USA: Statistical Analysis Systems Institute; 2002.
12. Aaslyng MD. Quality indicators for raw meat. Danish meat Research Institute, Roskilde, Woodhead Publishing Ltd; 2003.
13. Kim SH, Chin KB. Physico-chemical properties and changes of sarcoplasmic protein bands of chicken meat cuts with or without salt during cooking temperature. Korean Journal of Animal Science and Technology. 2007;49(2):269–278.
14. Banon S, Diaz P, Nieto G, Castillo M, Alvarez D. Modeling the yield and texture of comminuted pork products using color and temperature. Effect of fat/ lean ratio and starch. Meat Science. 2008;80(3): 649–655.
15. Huang SC, Shiau CY, Liu TE, Chu CL, Hwang DF. Effects of rice bran on sensory and physico-chemical properties of emulsified pork meatballs. Meat Science. 2005;70(4):613–619.
16. Luruena-Martinez MA, Vivar-Quintana AM, Revilla I. Effect of locust bean/xanthan gum addition and replacement of pork fat with olive oil on the quality characteristics of low-fat frankfurters. Meat Science. 2004; 68(3):383–389.
17. Yang HS, Choi SG, Jeon JT, Park GB, Joo ST. Textural and sensory properties of low fat pork sausages with added hydrated oatmeal and tofu as texture-modifying agents. Meat Sci. 2007;75(2):283-9.

18. Liu MN, Huffman DL, Egbert WR. Replacement of beef fat with partially hydrogenated plant oil in lean ground beef patties. Journal of Food Science. 1991; 56(3):861–862.
19. Park JC, Jeong JY, Lee ES, Choi JH, Choi YS, Yu LH. Effects of replaced plant oils on the quality properties in low-fat hamburger patties. Korean J Food Sci Technol. 2005; 37:412–417.
20. Hsu SY, Yu SH. Comparisons on 11 plant oil fat substitutes for low-fat Kung-wans. Journal of Food Engineering. 2002;51(3): 215–220.
21. Choi YS, Jeong JY, Choi JH, Han DJ, Kim HY, Lee MA, Kim HW, Paik HD, Kim CJ. Effects of dietary fiber from rice bran on the quality characteristics of emulsion-type sausages. Korean J. Food Sci. An. 2008; 28:14–20.
22. Bloukas JG, Paneras ED, Fournitzis GC. Effect of replacing pork backfat with olive oil on processing and quality characteristics of fermented sausages. Meat Science, 1997;45(2):133–144.
23. Choi YS, Choi JH, Han DJ, Kim HY, Lee MA, Kim HW, Lee JW, Chung HJ, Kim CJ. Optimization of replacing pork back fat with grape seed oil and rice bran fiber for reduced-fat meat emulsion systems. Meat Sci. 2010;84:212–218.
24. Paneras ED, Bloukas JG. Vegetable oils replace pork backfat for low-fat frankfurters. Journal of Food Science. 1994;59(4):725–728.
25. Kayaardi S, Gok V. Effect of replacing beef fat with olive oil on quality characteristics of Turkish soudjouk (sucuk). Meat Science. 2003;66(1):249–257.
26. Yildiz-Turp G, Serdaroglu M. Effect of replacing beef fat with hazelnut oil on quality characteristics of sucuk – A Turkish fermented sausage. Meat Science. 2008; 78(4):447-54.
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