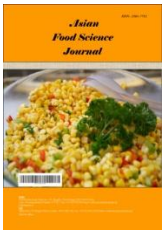

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Qualitative Evaluation of Lamb Meat Sausage Prepared with Different Antioxidants

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Consumer awareness and health consciousness has resulted in the use of natural additives or alternative methods to extend shelf life and improve food safety. The present study evaluated the quality and shelf-life of lamb meat sausage prepared with different natural antioxidants. The antioxidants (Turmeric, Garlic, Honey, Moringa and Ginger at 2% each) on the yield, sensory acceptability, chemical composition, lipid peroxidation, fatty acid profile and microbiological assay was studied in a completely randomized design. The results revealed that the turmeric, garlic and honey compared ($p>0.05$) favourably with the control in terms of yield and preferred ($p<0.05$) above others for colour, flavor, tenderness and overall acceptability. All the antioxidants have suppressing effects with lower values ($P<0.05$) on crude protein, ether extracts and lipid peroxidation as compared to the control. Variation exist in all the parameters of the fatty acid profile while the microbial loads of the lamb meat sausage samples showed a significant ($p<0.05$) reduction in the Total Bacterial counts (TBC), Total Coliform Counts (TCC) and Total Fungi Counts (TFC) for all samples prepared with natural antioxidants with the least values ($p<0.05$) reported in moringa samples as compared with others. Conclusively of the respective natural antioxidants in lamb meat sausage enhanced the cooking yield, nutrient composition and keeping qualities of the product and is therefore recommended for the product quality and safety.

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Keywords: Antioxidant; fatty acid profile; lamb meat; lipid oxidation; proximate composition; sausage.

1. INTRODUCTION

"Sausage is one of the oldest known forms of processed meat products and is very popular in many areas around the world. Sausages were invented to make the most of the leftovers of meat and entrails. Sausages can be defined as meat products that are manufactured by selecting, chopping, and mincing lean and fat, with or without offal, adding condiments, spices, additives, and starter culture" [1]. "The ingredients are stuffed into casings, ripened, cured, and in some cases smoked" [2,3].

"Lipid oxidation and growth of undesirable microorganisms in food products result in the development of spoilage, off-flavor, rancidity, and deterioration, rendering such products unacceptable for human consumption" [4-7]. Das et al. [8] reported that "they deteriorate the taste, colour, texture and nutrient contents of meat and meat products". "They also yield many compounds that contribute to the pathogenesis of cancer, atherosclerosis, heart and allergic diseases" [4,7].

"The most efficient and practical way to prevent oxidative and color deterioration of meat products is to incorporate antioxidants into formulations that could be natural or artificial" [9]. "Antioxidants are compounds or substances that can retard lipid oxidation and prolong the product's shelf life of meat" [10]. "However, the application of synthetic antioxidants has been recently restricted because of the suspicion that they are carcinogenic. Natural antioxidants are various substances with different chemical characteristics, which are widely present in plants. Antioxidants retard or inhibit the oxidation of other substances by inhibiting the initiation or propagation of oxidizing chain reactions" [11].

"Some authors have reported that natural antioxidants do not affect the sensory characteristics of meat and meat products. Spices and herbs have been added to food since ancient times, not only as flavoring agents but also as folk medicine and food preservatives" [12]. "Meat colour has been reported as the most important factor when consumers assess meat quality since they relate colour to freshness. However, colour does not correspond to differences in eating satisfaction" [13]. "Changes in meat colour are due to the oxidation of red oxymyoglobin to metmyoglobin (MMG), which give the meat an unattractive brown color" [6,12]. "For this reason, a growing interest has been paid to the research of natural antioxidants, among which spices occupy an important position" [14].

This study aimed at investigating quality attributes of lamb meat sausage with different natural antioxidants.

2. MATERIALS AND METHODS

The experiment was carried out at the Animal Products and Processing Unit, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo state, Nigeria. The lamb meat was bought from Teaching and Research slaughter slab, LAUTECH, and other ingredients such as spices, vegetable oil, and different natural antioxidants such as Garlic, Tumeric, Honey, Ginger, and Moringa were obtained from a local market in Ogbomoso, Oyo state.

2.1 Production of Lamb Meat Sausage

The lamb was slaughtered, scalded and eviscerated as described by Omojola and Adesehinwa (2006). The carcasses were deboned and trimmed off visible fat to reduce the fat content before grinding through 3 mm plate of Breville® stainless steel meat grinder. The ground mutton mixed with several ingredients in a food processor mixer for 3-5 minutes at 4-6 0C. The sausage batter was then prepared as shown in Table 1 and stuffed in a casing (ruminant casing) with an electrical operated stuffer (Breville® stainless steel meat grinder) to have 60 sausages (10 each for the respective antioxidant and the control) with diameter 1.6 cm and length 10 cm. The sausages were then labelled from Control, Turmeric, Garlic, Honey, Moringa and Ginger respectively. The sausages were then held 4 hours at 40C to allow for the ingredients to equilibrate. Afterward, the sausages were boiled at 85^0C for 20 minutes, and the products were cooled down at ambient temperature as presented in Fig. 1.

2.2 Organoleptic Evaluation

It was conducted using 10-member trained panelists according to the procedures of AMSA (14); Akinwumi and Odunsi [15]. Meat preparation was done using a wet cooking method. The prepared lamb sausages were served to 10-member taste panels drawn from students in the Faculty of Agricultural Science, Ladoke Akintola University of Technology, Ogbomoso. The semi-trained panelists evaluated the samples for colour, flavour, juiciness, tenderness, and general acceptability. The assessment was based on a 9-point hedonic scale. The score was arranged in descending order, and the maximum score of 9 was given to the extremely like condition while the lowest score of 1 was for the poorest condition.

2.3 Chemical Properties

Lamb sausage samples were analyzed for proximate composition and fatty acid profile by the procedures of AOAC [16].

2.4 Microbial Assay

The microbiological quality and safety of *suya* were assessed on the basis of Total Bacterial Count (TBC), Total Coliform Count (TCC) using Nutrient agar and MacConkey agar, respectively. The swabs from the samples were taken to the laboratory where samples were evaluated at 0 days and four weeks for microbial assay. Gram-staining, motility test, and biochemical test techniques were conducted for clear identification as described by [17] while fungi identification was carried out as described by [18,19].

2.5 Statistical Analysis

All data collected from this study were subjected to a one-way Analysis of Variance (ANOVA) using the SAS [20] analytical software.

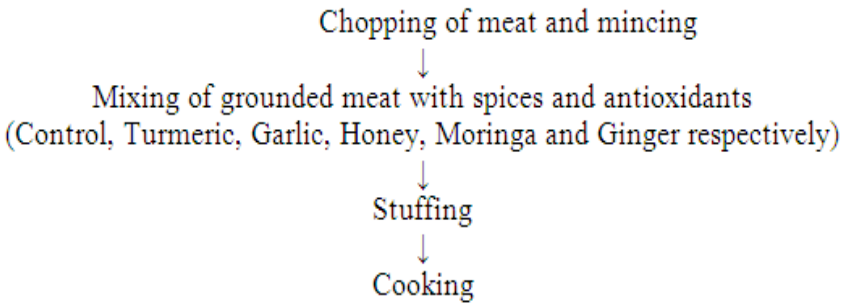

Fig. 1. Processing flow chart of lamb meat sausage prepared with different natural antioxidants

Table 1. Ingredients Composition of Lamb Meat Sausage prepared with different natural antioxidants

Ingredients	Control	Turmeric	Garlic	Honey	Moringa	Ginger
Lamb meat (mutton)	65	65	65	65	65	65
Binder (wheat flour)	20	20	20	20	20	20
Spices	3	1	1	1	1	1
Vegetable oil	6	6	6	6	6	6
Water	6	6	6	6	6	6
Natural antioxidants	-	2	2	2	2	2
Total	**100**	**100**	**100**	**100**	**100**	**100**

3. RESULTS AND DISCUSSION

Table 2. Cooking yield of lamb meat sausage with different natural antioxidants

Samples	Cooking yield (%)
Control	96.36[a]
Turmeric	95.83[a]
Garlic	95.90[a]
Honey	97.35[a]
Moringa	93.73[b]
Ginger	93.25[b]
SEM	2.05

[a,b] Mean with different superscripts in the same column differ significantly (p<0.05)

Table 3. Organoleptic properties of lamb sausage prepared with different antioxidants

Parameters	Control	Turmeric	Garlic	Honey	Moringa	Ginger	SEM
Colour	4.50[ab]	5.60[a]	5.00[ab]	3.60[b]	4.50[ab]	4.80[ab]	0.84
Flavour	4.40[b]	4.90[ab]	6.30[a]	4.20[b]	4.00[b]	4.30[b]	0.16
Tenderness	3.60[b]	5.00[a]	5.90[a]	5.10[a]	5.60[a]	5.80[a]	0.61
Juiciness	3.30	3.80	4.40	3.40	4.00	4.20	0.25
Texture	4.50	5.20	4.30	4.40	4.80	4.50	0.26
Overall Acceptability	6.20[a]	6.00[a]	4.20[b]	6.90[a]	5.60[a]	6.00[a]	0.21

[a,b] Mean with different superscripts in the same column differ significantly (p<0.05)

Table 4. Proximate composition and lipid peroxidation of lamb sausage prepared with different natural antioxidants

Parameters (%)	Control	Turmeric	Garlic	Honey	Moringa	Ginger	SEM
Crude protein	36.10[a]	34.72[b]	35.28[b]	35.01[b]	34.41[c]	33.90[d]	2.31
Ether extract	11.00[a]	9.23[b]	9.00[b]	8.76[b]	8.54[b]	9.00[b]	1.72
Ash	7.40	7.50	7.40	7.70	7.70	7.50	1.02
Moisture content	62.30[c]	74.86[a]	73.03[b]	73.08[b]	73.90[a]	59.85[c]	5.23
Lipid peroxidation **(**U/L**)**	19.61[a]	11.43[b]	11.43[b]	12.53[b]	12.78[b]	13.42[b]	1.23

[a,b] Mean with different superscripts in the same row differ significantly (p<0.05)

Table 5. Fatty acid profile of lamb meat sausage prepared with different antioxidants

Parameters (MEqL)	Control	Turmeric	Garlic	Honey	Moringa	Ginger
C12:0 SFA	4.22	6.11	4.30	2.00	4.34	6.05
C18:0 SFA	5.69	8.53	5.49	2.84	5.64	8.63
C16:0 SFA	5.42	7.79	5.16	2.56	5.12	7.69
C24:0 SFA	7.37	11.25	7.37	3.68	7.57	11.05
C17:0 SFA	5.45	8.12	5.44	2.70	5.41	8.21
C 20:4n-6 PUFA	6.48	9.23	6.68	3.04	6.58	9.13
C18:3n-3 PUFA	5.63	8.45	5.60	2.80	5.66	8.47
C18:1n-9 MUFA	5.67	8.47	5.65	2.82	5.55	8.47
Total SFA	15.33	41.80	27.76	13.78	28.08	41.63
Total PUFA	12.11	17.68	12.28	5.84	12.24	17.60
Total MUFA	5.63	8.47	5.65	2.82	5.55	8.47
Total FA	33.07	67.95	45.69	22.44	45.87	67.70

SFA- Saturated Fatty Acid
PUFA- Poly Unsaturated Fatty Acid
MUFA- Mono Unsaturated Fatty Acid, TFA- Total Fatty Acid

Table 6. Bacteria count of lamb meat sausage with different natural antioxidants

Samples	Total Bacteria Counts (TBC) cfu/g x 10^6	Total Coliform Counts (TCC) cfu/g x 10^4	Total Fungi Counts (TFC) cfu/g x 10^3
Control	5.54^a	6.54^a	6.12^a
Turmeric	1.24^c	4.32^b	5.32^b
Garlic	1.88^c	3.22^c	5.22^b
Honey	2.92^b	3.65^c	5.64^b
Moringa	1.19^c	2.76^d	2.34^c
Ginger	1.76^c	3.54^c	4.78^b
SEM	0.32	0.43	1.12

^{a,b} *Mean with different superscripts in the same column differ significantly (p<0.05)*

3.1 Results

Table 2 present the cooking yield of lamb meat sausage prepared with different natural antioxidants. The results revealed the sausage prepared with honey had the highest (p<0.05) coking yield (97.35%) while the least (p<0.05) value was found in those prepared with ginger (93.25%)

The organoleptic properties of lamb sausage prepared with different natural antioxidants are presented in Table 3. The results showed that tenderness, juiciness, and texture were not significantly affected (p<0.05) with the different antioxidants samples, while colour, flavour, and overall acceptability were significantly affected (p<0.05). The panelist rated turmeric, garlic, and honey the highest (p<0.05) for colour, flavour, and overall acceptability.

The proximate composition of lamb sausage prepared with different natural antioxidants is presented in Table 4. No significant (p>0.05) effects were reported in ash while variations (p<0.05) were observed in Crude protein, ether extract, dry matter, moisture contents and lipid peroxidation of the lamb sausage. The crude protein, ether extract and lipid peroxidation reduced (p<0.05) with the addition of various natural antioxidants.

Table 5 shows the Fatty acid profiles of lamb meat sausage prepared with different natural antioxidants. The result showed that there were difference values in all the fatty acids analyzed except in a few parameters of the samples that have the same values. The highest value was observed in turmeric (11.25) found in lignoceric acid and the lowest was observed in honey with (2.00) in lauric acid. Control that has no inclusion of natural antioxidants has close values similar to garlic in all the parameters analyzed. Turmeric and ginger have the same values of (8.47) in oleic acid, also the same values were observed in control and garlic (7.37) in lignoceric acid. Ginger has the highest values in all the parameters except in palmitic acid and lignoceric acid turmeric values were higher.

Table 6 shows the microbial load of lamb sausage prepared with different natural antioxidants.

The results showed significant (p<0.05) differences in the microbial load of the lamb sausage samples as the highest values (p<0.05) were reported in the control for TAC, TCC and TFC compared to those prepared with the antioxidants. However, the least values (p<0.05) were observed in sausage prepared with moringa.

3.2 Discussion

In general, lamb meat sausages treated with different antioxidants were rated better in colour, flavor, and overall acceptability than the control. These are the criteria the consumers see in a product before buying and consuming the products. Colour is one of the foremost sensory attributes for meat and meat products consumers since it is associated with freshness and quality [21,22] hence, the colour rating with this study favours the inclusion of antioxidants in lamb meat sausage. The results were also in agreement with Mohamed and Monsour [23] who reported that “the flavor score of patties prepared without the addition of antioxidants was significantly (p<0.05) lower than those of other samples treated with antioxidants and panelists detected a rancid flavor in the patties formulated without the addition of antioxidants”. Lorenzen et al. [24] demonstrated that “51% of consumers rated tenderness as the most important sensory trait they look for in meat and meat products”. The natural antioxidants obviously worked on the products resulting above the control. The

insignificant differences (P>0.05) among the various treatments for most sensory attributes (juiciness and texture) indicate that mutton sausages prepared by the addition of antioxidants were equally preferred as the control by consumers.

Similar findings of moisture content were obtained by Ahmed, et al. [25], and Alamin [26] which were 68% and 70.32%, respectively. Lower results for protein contents were reported by González-Tenorio et al. [27], and Alamin [26] which were 18.2%, and 18.53%, respectively. "The high moisture content could be due to the presence of fresh vegetables added to the in there study was attributed to adding too much filling of non-proteinaceous materials in the formulation of the product like the wheat flakes, root beet as a coloring and filling material which is consequently reflected in the final protein and meat content of the product" [28]. "The high-fat content of samples reported could be due to the unhealthy way of processing and extra fat-containing spread added to the burger samples. The high ash value could be due to the addition of spices as a seasoning, high fiber vegetables, starches, cereals, soy proteins, and salt. Soft bone and other parts in the patty could also increase the ash content due to the presence of calcium and other macrominerals" [28]. "The values reported in this study, compared favourably with the standard reported by Khairy et al. [28] where moisture, protein, fat, ash, and yield are 60%, 15%, 30%, 5%, and 60%, respectively".

The PUFA/SFA ratio is one of the major parameters used to assess the nutritional quality of the lipid fraction of foods. "Nutritional guidelines recommend a PUFA/ SFA ratio above 0.4 [29] although several researchers reported that this ratio must be considered together with PUFA n-6/n-3 ratio due to the beneficial effect of linoleic acid (n-6) on health that is produced only when PUFA/SFA ratio is no greater than 1.5. SFA are considered to raise plasma cholesterol, except for stearic acid which reduces total and LDL cholesterol; therefore, the content of this fatty acid (stearic) is subtracted from the SFA fraction when the association between food saturated fatty acids and risk of heart diseases is studied". Moreover, "MUFA have hypocholesterolemic effect, but they do not decrease HDL cholesterol, which protects against cardiovascular diseases. Therefore, PUFA/SFA-stearic ratio if calculated for these products as shown in Table 5 were similar to those reported by other researchers, such as traditional Spanish fermented sausage: 0.43 [30], Brazilian salami 0.44 [31], Spanish salchichón 0.49 [32], and Italian salami 0.50" [33]. It was observed from the values obtained in honey that its chemical composition has a low significant effect on all the parameters of fatty acid analyzed while the sample with ginger suggests its chemical component greatly contributes to the fatty acid analyzed.

"The sausage products studied have n-6/n-3 ratios higher than those suggested by International Health Organizations, which is in agreement with Jimenez-Colmenero [34], who reported that meat products show n-3 PUFAs are present in very low levels". Fatty acids from each sample (control, turmeric, garlic, honey, moringa, and ginger) were affected by the inclusion of a specific natural antioxidant. An increase was observed for turmeric and ginger, while honey values decreased. An increase in polyunsaturated fatty acids (PUFAs) after cooking has been observed in other studies. Maranesi et al. [35] observed an increase in polyunsaturated fatty acid (PUFA) in the ribs of loins after boiling and microwaving followed by final grilling. Some authors [36] have found an increase in polyunsaturated fatty acid (PUFA) levels of meat and meat products after cooking due to the lipid losses, containing mainly triacylglycerols of adipose tissues with relatively more saturated fatty acid (SFA) than polyunsaturated fatty acid (PUFA), as suggested by Romero et al. [37].

"The addition of antioxidants is, therefore necessary to increase the storage stability, sensory quality, and nutritional value of animal products" as reported by Romero et al. [37]. "Due to the positive health effects of long-chain n-3 polyunsaturated fatty acids (PUFA), there is an increased interest to produce meat products rich in n-3 polyunsaturated fatty acids" [37]. Increasing the amount of easily oxidized polyunsaturated fatty acid (PUFA) in animal products, however, will also require a higher content of antioxidants in the end-product to protect the nutritional valuable fatty acids (FA).

"The nutritional composition of meat products provides an appropriate environment for the growth and proliferation of food borne pathogens" [38]. "Therefore, pathogen bacteria may contaminate sausage during processing which has contributed to food borne disease globally. Moreover, these products are known as

a high risk food group. It is known that microorganisms can contaminate sausage from meat, spices and other ingredients as well as the environment, handlers and equipment, particularly slicing machines and cutting utensils during processing that can have an important effect on the microbiological properties of the products" [38]. "Based on epidemiological and microbiological studies, cross-contamination during processing and subsequent bacterial growth is the major reason of meat product contamination and disease. Absent sanitizing and washing and improper cleaning procedures of slicer blades would lead to contamination of slicing machines that increase food borne disease in consumers" [39]. "Therefore, training and supervision are hereby encouraged to ensure appropriate hand washing, proper cleaning and sanitizing in order to reduce cross-contamination" [38]. "The present results showed that the total bacterial count decreased significantly ($P<0.05$) with natural antioxidants included as the average bacterial load of the fresh and frozen samples of camel sausages were (3×10^6 and 2×10^6 CFU/gm) respectively. The sample with moringa has the lowest counts. This result was in agreement with that reported by Siham and Daoud" [40]. The present results showed that total bacterial count decreased significantly ($P<0.05$) with natural antioxidants included, this result is matching with that reported by Siham and Daoud [40].

4. CONCLUSION

The cooking yield favoured sausage produced with honey while those with turmeric, garlic and honey gave better results with the sensory parameters. Although the proximate and the lipid peroxidation were reduced with the inclusion of the antioxidants, turmeric and ginger have increased levels of fatty acids. Inclusion of moringa in the sausage greatly reduced the microbial loads while other antioxidants also gave preferred microbial loads compared to the control.

5. RECOMMENDATION

The inclusion of the natural antioxidants in this study is hereby advocated for improved nutrients composition and enhanced shelf life of sausage meat products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bowser JT, Mwavita M, Al-Sakini A, McGlynn W, O. Maness N. Quality and Shelf life of fermented lamb meat sausage with Rosemary Extract. Open Food Sci J. 2014;8(1):22-31.
2. Leroy F, Verluyten J, De Vuyst L. Functional meat starter cultures for improved sausage fermentation. Int J Food Microbiol. 2006;106(3):270-85.
3. Olivares A, Navarro JL, Salvador A, Flores M. Sensory acceptability of slow fermented sausages based on fat content and ripening time. Meat Sci. 2010;86(2):251-7.
4. Lima DM, Rangel A, Urbano S, Mitzi G, Moreno GM. Oxidação lipídica da carne ovina. Acta Vet Bras. 2013;7(1):14-28.
5. Ding Y, Wang SY, Yang DJ, Chang MH, Chen YC. Alleviative effects of litchi (*Litchi chinensis* Sonn.) flower on lipid peroxidation and protein degradation in emulsified pork meatballs. J Food Drug Anal. 2015;23(3):501-8.
6. García-Lomillo J, Gonzalez-SanJose ML, Del Pino-García R, Ortega-Heras M, Muñiz-Rodríguez P. Antioxidant effect of seasonings derived from wine pomace on lipid oxidation in refrigerated and frozen beef patties. LWT Food Sci Technol. 2017;77:85-91.
7. Amaral AB, da Silva MV, da Silva Lannes SC. Lipid oxidation in meat: mechanisms and protective factors. Annu Rev Food Sci Technol, Campinas. 2018;38;Suppl 1:1-15.
8. Das AK, Nanda PK, Bandyopadhyay S, Banerjee R, Biswas S, McClements DJ. Application of nanoemulsion[1]based approaches for improving the quality and safety of muscle foods: A comprehensive review. Compr Rev Food Sci Food Saf. 2020;19(5):2677-700.
9. Kong B, Zhang H, Xiong YL. Antioxidant activity of spice extracts in a liposome system and in cooked pork patties and the possible mode of action. Meat Sci. 2010;85(4):772-8.
10. Shah MA, Bosco SJ, Mir SA. Plant extracts as natural antioxidants in meat and meat products. Meat Sci. 2014;98(1): 21-33.
11. Rather SA, Masoodi F, Akhter R, Rather JA, Shiekh KA. Advances in use of natural antioxidants as food additives for improving the oxidative stability of meat products. Madridge. J Food Technol. 2016;1:10-7.

12. Falowo AB, Fayemi PO, Muchenje V. Natural antioxidants against lipid–protein oxidative deterioration in meat and meat products, A review. Food Res Int. 2014;64:171-81.
13. Aminzare M, Hashemi M, Ansarian E, Bimkar M, Azar HH, Mehrasbi MR et al. Using natural antioxidants in meat and meat products as preservatives. A review. Adv Anim Vet Sci. 2019;7(5):417-25.
14. American Meat Science Association. Research Guidelines for cooking and sensory evaluation and instrumental tenderness measurement of meat (AMSA) Chicago, Illinois, USA. 2nd ed Version; 2015.
15. Akinwumi AO, Odunsi AA. Meat Quality of Broiler Chicken as affected by Strain, Age at Slaughter and Immobilization Methods. Int J Sci Res (IJSR). 2016;5(9):1318-24.
16. AOAC. Association of Official Agricultural Chemists, official methods of analysis of AOAC International. 20th ed. Rockville: AOAC International; 2016.
17. Cheesebrough M. District laboratory practice in tropical countries. Cambridge, UK: Cambridge University Press. 2000;76-100.
18. Ochei J, Kolkhatkar A. Medical laboratory science: theory and practice. New Delhil, India. Tata: McGraw-Hill; 2000.
19. Akinleye SB, Omojola AB, Rashidat KO. Nutritional quality of suya prepared from mutton using different types of muscles. Asian Food Sci J. 2019;6(3):1-8.
20. SAS. Statistical Analysis System Institutes. User's guide. Cary, NC: SAS Institute Inc; 1999.
21. Deraz SF, Khalil AA. A model system for conversion of metmyoglobin to bright red myoglobin derivatives in organic sausages using potential probiotic lactic acid bacteria. S. Asian. J Life Sci. 2018;6:22-35.
22. Zhu Y, Yang Q. Isolation of antibacterial, nitrosylmyoglobin forming lactic acid bacteria and their potential use in meat processing. Front Microbiol. 2020;11:1315.
23. Mohamed HMH, Mansour HA. Incorporating essential oils of marjoram and rosemary in the formulation of beef patties manufactured with mechanically deboned poultry meat to improve the lipid stability and sensory attributes. LWT Food Sci Technol. 2012;45(1):79-87.
24. Lorenzen CL, Miller RK, Taylors JF, Neely TR, Tatum JD, Wise JW et al. Beef customer satisfaction: trained sensor panel ratings and Warner-Bratzler shear force values. J Anim Sci. 2003;81(1):143-9.
25. Ahmed WA, Ahmed DA, Ahmed HE, Eltaib WA. Study on the wholesomeness of beef sausage processed by butcheries in Khartoum State and conformity to Sudanese Standards and metrology. Sudan J Sci Technol. 2013;14(1):25-32.
26. Alamin SA. Chemical composition of different types of sausage. Am Int J Res Humanit Arts Soc Sci. 2016;13(2):151-4.
27. González-Tenorio R, Fernández-Diez A, Caro I, Mateo J. Comparative assessment of the mineral content of a Latin American raw sausage made by traditional or nontraditional processes. At Absorption Spectrosc. 2012;12:167-82.
28. Khairy N, Karmi M, Maky MA. Proximate composition analysis of beef sausage. Aswan Univ J Environ Stud (AUJES). 2021;2(3):155-61.
29. World Health Organization (WHO). Technical Report Series. no. 916 (TRS 916). Diet, nutrition and the prevention of chronic diseases. Geneva. 2003;87-8.
30. Muguerza E, Gimeno O, Ansorena D, Bloukas JG, Astiasarán I. Effect of replacing pork backfat with preemulsified olive oil on lipid fraction and sensory quality of Chorizo de Pamplona – a traditional Spanish fermented sausage. Meat Sci. 2001;59(3):251-8.
31. de Campos RML, Hierro E, Ordóñez JA, Bertol TM, Terra NN, de la Hoz L. Fatty acids and volatile compounds from salami manufactured with yerba mate (Ilex paraguariensis) extract and pork back fat and meat from pigs fed on diets with partial replacement of maize with rice bran. Food Chem. 2007;103(4):1159-67.
32. Rubio B, Martínez B, Sánchez MJ, Dolores García-Cachán MA, Rovira J, Jaime I. Study of the shelf life of a dry fermented sausage salchichon made from raw material enriched in monounsaturated and polyunsaturated fatty acids and stored under modified atmospheres. Meat Sci. 2007;76(1):128-37.
33. Del Nobile MA, Conte A, Incoronato L, Panza O. Seyi, A. and Marino, R. New strategies for reducing the pork backfat content in typical Italian salami. Meat Sci. 2009;81:263-9.
34. Jiménez-Colmenero F. Healthier lipid formulation approaches in meat-based functional foods. Technological options for

replacement of meat fats by non-meat fats. Trends Food Sci Technol. 2007;18(11): 567-78.
35. Maranesi M, Bochicchio D, Montellato L, Zaghini A, Pagliuca G, Badiani A. Effect of microwave cooking or broiling on selected nutrient contents, fatty acid patterns and true retention values in separable lean from lamb rib loins, with emphasis on conjugated linoleic acid. Food Chem. 2005;90(1-2):207-18.
36. Gerber N, Scheeder RL, Wenk C. The influence of cooking and fat trimming on the actual nutrient intake from meat. Meat Sci; 2008.
DOI: 10.1016/j.meatsci.2008.07.012
37. Romero MC, Romero AM, Doval MM, Judis MA. Nutritional value and fatty acid composition of some traditional Argentinean meat sausages. Food Sci Technol, Campinas. 2013;33(1):161-6.
38. Ehrampoush MH, Mazloomi SM, Zarei S, Hemmati F, Ghaneian MT, Hajimohammadi, B, and Dehghan, A. Int J Nutr Sci. Microbiological Quality of Sausage during Slicing at Food Retail Stores in Shiraz, Iran. 2017;2(1):21-6.
39. Osimani A, Aquilanti L, Clementi F. Microbiological quality of meat-based meals and operation of control systems within a food service environment. Int Food Res J. 2015;22: 1692-8.
40. Siham AA, Daoud AA. A study of total bacterial count and organoleptic examination of different types of sausages in the Sudan. IOSR JAVS (IOSR-JAVS). 2015;8(8):18-23.

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