Effect of Natural Antioxidants on Quality and Keeping Quality of Suya from Mutton Subjected to Different Processing Methods

Abstract

This study evaluated the effect of breeds, processing methods, natural antioxidants and storage period of *Suya* from mutton. A total 12 sheep (6 each from Balami and Ouda) were weighed, slaughtered and allotted to 3 processing methods which are scalding, singeing and skinning. They are processed into *Suya* meats prepared with 4 different natural antioxidants (black pepper, green tea, roselle and clove) and preserved for 4 weeks. The samples were evaluated for chemical composition, organoleptic properties, microbial loads and storage period. Data collected were analysed using factorial arrangement of 2x3x4. The results showed that natural antioxidants significantly ($P<0.05$) influenced all parameters measured except dry matter with the highest value of CP (60.28%) observed in *Suya* samples spiced with black pepper. There were significant ($P<0.05$) in all the parameters evaluated using different processing methods. Breed had no significant ($P>0.05$) on organoleptic properties. Significance ($P<0.05$) effect was observed on colour for processing methods with the highest value 5.18 in scalding. Natural antioxidants had significant ($P<0.05$) on organoleptic properties except flavour. Although, highest value for overall acceptability (6.60) was found in *Suya* spiced with clove. However, breed no significant ($P>0.05$) on all the microbial counts of *Suya* samples. Scalding had lowest ($P<0.05$) values for all the microbial parameters measured. Natural antioxidants significantly ($P<0.05$) affect all the parameters evaluated with highest total bacterial count (TBC) $9.34x10^6$, total coliform count (TCC) $9.21x10^4$ and total yeast count (TYC)$10.23x10^3$ in the control while the lowest TBC ($4.31x10^6$), TCC ($5.26x10^4$) and TYC ($5.46x10^3$) found in the samples spiced with clove. Storage for 4 weeks had higher significant ($P<0.05$) values in all the parameters measured than those evaluated for microbial loads at 0 day. It is therefore concluded that, samples spiced with clove had lower microbial loads which tend to enhance shelf-life and were most acceptable for consumption.

Keywords: Suya, Natural antioxidants, Mutton, Scalding, Microbial loads

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INTRODUCTION

Meat and meat products are major source of protein and an important source of vitamins for most people in many parts of the world, thus they are essential for the growth, repair and maintenance of body cells which is necessary for our everyday activities. The biological and chemical characteristics of meat make it an excellent medium for the growth of microorganisms that produce undesirable sensory changes, which is why processing and preservation methods are aimed at delaying or inhibiting microbial growth to increase the shelf life of fresh meat (Borch *et al.*, 1996). Singeing, scalding, and skinning are the processing methods that are extensively used for dressing animal carcass post-mortem (Hassan *et al.*, 2018) while processed meat is any meat which has been modified in order to either improve its taste or extend its shelf life (Inyang *et al.*, 2005).

Suya is primarily prepared from the boneless meat of animals (Abdullahi *et al.*, 2004). Muscles meat of almost any kind can be used to increase its keeping quality. It is a popular, traditionally processed, ready to eat Nigerian meat product, which may be served or sold along the streets, in club houses, at picnics, parties, restaurants and within institutions. *Suya* is one of such intermediate

moisture product that is easy to prepare and highly relished (Omojola *et al.*, 2004). There are three types of suya namely; *Tsire*, *Kilishi*, *Balangu.* The process of preservation commences after the whole period of dressing i.e Scalding, singeing, decapitation, evisceration etc. have been completed (Adeshinwa, 2006). Today, *Suya* meat has gained wide popularity and it is been consumed by majority. Most of the sellers of this processed meat were found in strategic locations and were people who does not have much formal education and as a result still uses traditional methods of handling, processing and packaging the products, which are considered to be unhygienic, unsafe and can result in rapid deterioration of the processed meat if not consumed within a short period of time (Olaoye *et al*., 2016).

The intentions of preservation methods are to inhibit the microbial spoilage and to minimize the oxidation and enzymatic spoilage. Since meat has a high nutritive value, microorganisms could easily grow on it. The possible sources of contamination are through slaughtering of sick animals, washing the meat with dirty water, handling by butchers, contamination by flies, processing close to sewage or refuse dumps environment, spices, transportation and use of contaminated equipment such as knife and other utensils (Igyor and Uma, 2005*).* Microorganisms grow on meat causing visual, textural and organoleptic changes when they release metabolite (Jackson *et al*., 2001). A lot of factors affect the growth of micro organisms on meat. These factors include temperature, pH, water availability and presence of nutrients, moisture, acidity (intrinsic factors), gaseous requirement, and atmosphere of storage (extrinsic factors) (Nester *et al*., 2001).

Antioxidants are substances that delay or prevent the oxidation of biomolecules in meat. Antioxidants are added to different meat products to prevent lipid oxidation, improve quality and nutritional value of meat. They can be classified into natural and synthetic antioxidant. To avert the effects of oxidation in meat, chemical antioxidants are extensively used. However, because of the possible health risk and toxicity, natural antioxidants are extensively used due to increase demand by consumers. Natural antioxidants are plant derived antioxidant which includes Rosemary Black pepper, Roselle, Green Tea, Clove, Ginger and others (Zhang *et al.*, 2016). Therefore, this study evaluated effect of natural antioxidants on nutrient and keeping quality of suya from mutton subjected to different processing methods.

MATERIALS AND METHODS

Experimental Samples

Twelve sheep (6 each for Balami and Ouda) were purchased from a reputable ruminant animal market in Ibadan and transported to the Livestock unit of Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Oyo State. Ingredients such as ginger, red pepper, salt, seasoning, vegetable oil, and groundnut cake powder, and test ingredients such as Roselle, Clove, Green tea and Black pepper were purchased from a reputable market in Ogbomosho, Oyo State. The animals were stabilized for optimum condition for two weeks before slaughtering. The experimental animals (6 per breed) were slaughtered and processed using three different methods (Scalding, Skinning, and Singeing).

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Suya Preparation

The raw meats were washed and cut into thin fillets. The ingredient was spread on a clean, dry tray and each sheet of meat was properly dusted and soaked with the ingredient according to methods of (Omojola, 2008). The sticks of meat were labeled and about 5–10 ml of groundnut

oil was sprinkled on each meat stick before roasting using traditional suya smoker. The meats were allowed to stay on the fire at 90°C for 20 minutes with the distance of 22–23 cm from the center of the fire and intermittent turning of the product. Additional groundnut oil was sprinkled on the meat while roasting continued (Omojola, 2008). The suya prepared from the 3 dressing methods were labeled accordingly for easy identification. The ingredients composition as described by (Omojola, 2008) was used for the production of suya while ginger was replaced with the different natural antioxidants at 10% each (Table 1). All necessary hygienic precautions were observed in the laboratory

Table 1: Ingredients Ccomposition of Sspices and Ccondiment for Ssuya Pproduction

Ingredients	Control	Black pepper	Green tea	Roselle	Clove
Groundnut powder	52.00	52.00	52.00	52.00	52.00
Ginger	10.00	10.00	10.00	10.00	10.00
Dried pepper	10.00	10.00	10.00	10.00	10.00
White pepper	5.00	5.00	5.00	5.00	5.00
Salt	8.50	8.50	8.50	8.50	8.50
Curry	5.00	5.00	5.00	5.00	5.00
Maggi seasoning	7.50	7.50	7.50	7.50	7.50
Groundnut oil	2.00	2.00	2.00	2.00	2.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

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Figure 1: Fflow Cchart for Ssuya pPreparation

Raw meat→ washed → sliced → skewed in thin stick → spiced → kept in transparent plastic container for 30-60 minutes → roasted → spiced → heated for 5-8 minutes → sprinkled vegetable oil → packaged.

Data Ccollection

Proximate Ccomposition

The proximate composition of dry matter, crude protein, ~~ether~~and ether extract and ash contents was determined for *suya* samples using standard analytical methods of AOAC (2000), while the amount of nitrogen-free extract was calculated by differences.

Sensory Eevaluation

Suya samples were cut into uniform size, coded and served warm for organoleptic properties assessment. A 9-point hedonic scale was used to assess the following categories of the *suya* samples: colour, flavour, tenderness, juiciness and overall acceptability. Scores were assigned with 9 being ''like extremely" and 1 ''dislike extreme". Semi-trained panelist received a piece of *suya* samples with a different tag for sensory evaluation. Water and cream cracker biscuits were provided for each panelist to freshen their mouth between each sample assessment.

Microbiological Load

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 4 weeks for microbial assay. Gram-staining, motility test, and biochemical test techniques were conducted for clear identification as described by (Cheesebrough, 2000) while fungi identification was carried out as described by (Ochei and Kolkhatkar, 2000).

Statistical Analysis of Data

Data collected were subjected to One-way ANOVA using SAS (1999). Significant means were separated by Duncan option of the same statistical software. A probability of 5% was considered significant (P<0.05).

Table 2: Main effect on Chemical Composition of Suya with Different Antioxidant subjected to Different Processing Methods

Parameters	DM(%)	CP(%)	EE	Ash	NFE	CHO	TAG	HDL	LDL	MDA
Breeds										
Balami	76.84	59.18	10.49	4.52	2.62	299.65^{a}	127.25^{a}	71.70	202.50^{a}	10.95
Ouda	77.59	59.32	10.28	5.08	2.91	262.00^{b}	113.90^{b}	70.21	169.00^{b}	10.22
SEM	3.92	2.52	1.32	0.52	0.65	3.21	3.01	1.24	3.42	1.40
Processing methods										
Scalding	71.46^{c}	55.91^{c}	7.45^{c}	3.79^{b}	4.30^{a}	276.40^{b}	107.82^{b}	70.95^{b}	183.89^{b}	11.57^{a}
Singeing	79.88^{b}	60.43^{b}	11.62^{b}	5.66^{a}	2.27^{b}	282.28^{b}	133.40^{a}	74.54^{a}	181.06^{b}	11.05^{a}
Skinning	83.02^{a}	63.51^{a}	13.88^{a}	5.00^{a}	0.55^{c}	305.60^{a}	127.00^{a}	64.53^{c}	215.70^{a}	8.05^{b}
SEM	2.31	2.11	1.32	1.02	0.34	3.41	2.32	2.10	2.31	1.23
Natural antioxidants										
Control	77.83	60.09^{a}	10.99^{a}	4.61^{b}	2.11^{b}	184.20^{e}	131.90^{b}	61.03^{b}	96.81^{d}	11.68^{b}
Black Pepper	78.77	60.28^{a}	11.27^{a}	4.79^{b}	2.42^{b}	231.20^{d}	130.40^{b}	74.96^{b}	130.20^{c}	8.27^{c}
Green Tea	76.02	57.60^{b}	10.39^{b}	4.61^{b}	3.37^{a}	306.10^{c}	81.37^{c}	39.13^{c}	250.70^{a}	7.70^{d}
Roselle	76.24	58.64^{b}	9.21^{c}	4.66^{b}	3.74^{a}	332.80^{b}	129.30^{b}	99.04^{a}	207.90^{b}	12.73^{a}
Clove	76.86	59.56^{a}	10.17^{b}	5.03^{a}	2.04^{b}	368.60^{a}	136.60^{a}	81.35^{ab}	259.90^{a}	12.90^{a}
SEM	2.13	2.11	1.34	1.21	0.21	4.21	3.21	2.13	2.12	2.31

^{abc} Means on the same row with different superscripts are statistically significant ((p<0.05). SEM: Standard Error of Mean.

DM – Dry Matter, CP – Crude Protein, EE – Ether Extract, NFE – Nitrogen Free Extract, CHO – Cholesterol, HDL – High Density Lipoprotein, LDL – Low Density Lipoprotein, MDA – Malondialdehyde

Table 3: Main effect on Organoleptic Properties of *Suya* with Different Natural Antioxidant subjected to Different Processing Methods

Parameters	Colour	Flavour	Juiciness	Tenderness	Overall Aacceptability
			Breeds		
Balami	4.25	4.49	4.66	4.90	5.72
Ouda	4.32	5.17	5.14	4.73	6.34
SEM	0.17	0.19	0.16	0.16	0.19
			Processing methods		
Scalding	5.18[a]	4.66	4.98	5.74	5.96
Singeing	3.78[b]	4.83	4.66	4.73	6.04
Skinning	3.48[b]	4.84	4.95	4.62	5.84
SEM	0.24	0.28	0.23	0.23	0.27
			Natural Aantioxidants		
Control	4.32[a]	4.52	4.88[ab]	4.36[b]	5.56[b]
Black pepper	4.71[a]	4.77	4.47[b]	5.04[ab]	5.56[b]
Green tea	5.00[a]	5.12	5.20[a]	5.00[ab]	6.20[ab]
Roselle	3.08[b]	4.48	5.08[ab]	5.24[a]	5.92[ab]
Clove	4.28[a]	4.92	4.63[ab]	4.50[ab]	6.60[a]
SEM	0.23	0.27	0.22	0.23	0.27

[abc] Means on the same row with different superscripts are statistically significant ((p<0.05). SEM: Standard Error of Mean.

Table 4: Main Eeffect on Mmicrobial lLoads of *Suya* with Ddifferent nNatural aAntioxidant subjected to Ddifferent Ppprocessing Mmmethods

Parameters	Mean Bbacterial ccCount cfu/g x10^6	Mean Ttotal Ccoliform Ccount cfu/g x 10^4	Mean Ttotal Yyeast and Mmould cfu/g x 10^3
		Breeds	
Balami	7.35	8.03	7.23
Ouda	6.13	7.91	8.28
SEM	0.63	0.21	0.33
		Processing Mmmethods	
Scalding	7.15[c]	7.12[b]	8.34[c]
Singeing	8.72[b]	7.82[b]	10.36[a]
Skinning	10.3[a]	10.36[a]	12.53[a]
SEM	1.29	1.03	0.92
		Natural Aantioxidants	
Control	9.34[a]	9.21[a]	10.23[a]
Black pepper	6.32[b]	7.56[b]	7.21[b]
Green tea	6.62[b]	7.39[b]	6.76[b]
Roselle	5.27[c]	6.16[c]	6.01[c]

Clove	4.31[d]	5.26[d]	5.46[d]
SEM	1.29	1.03	0.92
		Storage	
0 day	6.52[b]	6.01[b]	7.02[b]
4 weeks	9.39[a]	9.25[a]	10.21[a]
SEM	0.34	0.21	0.45

Results

Chemical Ceomposition

Chemical composition as affected by ~~breeds,~~breeds: processing methods and natural antioxidants on *suya* meat product is presented in Table 2. The results showed that the CHO, TAG and LDL were significantly (P<0.05) were the highest for balami breed. Although, ouda breed had the values for dry matter, ash and NFE. Furthermore, processing methods significantly (P<0.05) influenced the chemical composition of *suya* with different antioxidants. Highest DM, CP, EE, CHO, LDL and MDA were observed in skinning processing method. Although, natural antioxidant did not have significant (P>0.05) effect on DM whereas other parameters were significantly (P<0.05) affected by the natural antioxidants. Highest value of DM, CP and EE were observed in *suya* processed with black pepper. However, highest CHO, TAG, LDL and MDA were recorded for *suya* processed with clove.

Sensory Eevaluation

Organoleptic properties of *suya* with different antioxidant subjected to different processing methods are presented in Table 3. Breeds had no significant (P>0.05) influence on the *suya* prepared with different natural antioxidants. Though, the taste panelist scored *suya* obtained from ouda breed the highest in terms of flavour, juiciness and overall acceptability. Only flavour was significantly (P<0.05) influenced by processing methods. Meat samples (*suya*) processed by scalding was rated the highest for colour, juiciness and tenderness. However, natural antioxidants significantly (P<0.05) influenced organoleptic properties except flavour. The panelist rated colour the lowest in *suya* prepared with Roselle. Although, highest overall acceptability was observed in *suya* processed with Clove.

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Microbial ~~l~~Load ~~c~~Counts

Table 4 shows microbial loads count of *suya* with different natural antioxidants subjected to different processing methods. Breed of the animals did not significantly (P<0.05) influenced the microbial load of the *suya*. However, balami breed had the highest total bacterial and coliform counts while highest total yeast and mould counts was observed in *suya* obtained from ouda breed of sheep. Processing methods, natural antioxidants and storage significantly (P<0.05) affected the microbial counts of the *suya*. Skinning method was observed to have the highest total bacterial, coliform, yeast and mould counts while lowest values were observed in scalding processing method. The *suya* prepared without any natural antioxidant (control) was observed to have the highest microbial load counts while the lowest values were obtained from *suya* prepared with clove. *Suya* stored for four (4) weeks had significant (P<0.05) highest microbial counts and the lowest values were recorded those with 0 day storage.

Discussion

The chemical composition of *Suya* with different natural antioxidants subjected to different processing methods is as shown in Table 2. According to Akinleye *et al*. (2018) protein is the most important muscle constituent of which is made up of myofibrilla, sarcoplasmic and connective tissues. Highest CP (60.28%) was recorded in samples prepared with black pepper while lowest CP (57.60%) in *Suya* sample prepared with green tea. Ether extract of *Suya* prepared with black pepper was higher than other prepared with other natural antioxidants. The MDA of *Suya* processed by skinning is the lowest among the processing methods (scalding, singeing and skinning). Malondialdehyde is the most abundant aldehyde that results from lipid peroxidation and highly toxic molecule. *Suya* prepared with green tea had lower MDA which is an indication of reduced level of toxicity molecule in the *Suya* samples. This report agreed with the findings of McCarthy *et al.* (2001) who stated that the catechins present in green tea leaves was the most effective in reducing lipid oxidation frozen and fresh pork patties. Although, black pepper tended to decrease the LDL but lowest value of LDL was observed in the control. However, highest level of ash content was observed in *Suya* prepared using clove is in agreement with the report of Akinola *et al.* (2019). Ash content is often seen as an index of mineral content in biological mass (Effiong and Udo, 2010). Although, the highest DM observed in *Suya* processed by skinning shows that the meat can be stored for a longer period (Akinola *et al.*, 2019).

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From Table 3, the significance effect observed in *Suya* samples prepared with clove is in consonance with the report of Abubakar *et al.* (2021) who asserted similar scoring by the panelist for juiciness, tenderness and acceptability. Highest level of juiciness observed in *Suya* prepared with Roselle is an impression of moisture released during chewing and salivation produced by flavour factor (Omojola *et al*., 2003). Numerically, *Suya* obtained from Ouda breed had higher values of colour, flavour, juiciness, tenderness and overall acceptability. The result obtained for the overall acceptability shows that the consumers (panelist) prefer *Suya* prepared with clove.

The microbial load of *Suya* with different natural antioxidant subjected to different processing methods is presented in Table 4. Meat contains all the nutrients necessary for microbial growth and metabolism, making it susceptible to microbial contamination (Nwakanma *et al*., 2015). *Suya* stored for 4 weeks had higher Total Bacterial Counts (TBC), Total Coliform Counts (TCC) and Total Yeast Count (TYC) than those assessed for microbial load count at 0 day. Mandee *et al*. (2003) stated that the kind and number of micro organisms found on frozen meat is as a result of the freezing temperature of storing which can lead to death of the micro organisms. According to Kamala-Kumari *et al.* (2019) natural antioxidants have tendencies to reduce microbial growth, lipid peroxidation and improve product shelf-life. The *Suya* prepared with clove has the lowest TBC, TCC and TYC. This report is in line with the report of Jayathilakan *et al.* (2007). The TBC obtained in this study for Ouda (6.13) falls below the report of Salihu *et al*. (2020) who reported 8.90 TBC. Meanwhile, the TBC for Balami in this study (7.35) is higher than what was reported (4.60) by the same author. Although, higher TCC were reported for Ouda (7.91) and Balami (8.03) than what was reported by Salihu *et al*. (2020) for Ouda (3.46) and Balami (1.10). All these are still within the acceptable range for human consumption.

According to International Commission on Microbiological Specifications for Food Microorganisms in Foods ICMSF (1996) and London Health Protection Agency, LHPA (2009)

spoilage in meat products becomes evident when the bacterial counts exceed international guidelines of good manufacturing practice 10^7 cfu/g. For this study, meat products prepared from three processing methods (Skinning, Singeing and Scalding) did not exceed threshold levels for bacteria count, coliform count and fungal count that could cause microbiological spoilage of the meat products. Natural antioxidants have abilities to retard microbial growth, lipid oxidation and prolong product shelf-life (Kamala Kumari *et al.,* 2019) which was evident in this study. The samples with clove have the lowest counts. This result agreed with that reported by (Mandee *et al*., 2003) who stated that microbes are sensitive to clove, and other antimicrobial activities as clove and its essential oil was among the most capable antioxidants for controlling bacteria such as Escherichia coli (Mandee *et al*., 2003). Storage effect resulted in higher TBC, TCC and TYC. This agrees with the report of Mandee *et al*., (2003) that the kind and number of microorganisms found on frozen meat depend on freezing temperature during storage and severity of freezing process with respect to lethality to microorganisms. Complete death of all the microorganisms does not occur merely due to low temperatures and when the food is thawed there can be a rapid multiplication of microorganisms (Sivasanker, 2005).

Conclusion

Skinning is suitable processing method because it had higher level of dry matter and crude protein. Though, green tea reduced the malondialdehyde in the *Suya* samples. The overall acceptability for the *Suya* prepared with clove is the highest. All the natural antioxidants reduced the microbial loads of the samples, thereby improving the quality and shelf-life but storage of the *Suya* product could be deleterious.

References

Abdullahi, I. O., Umoh, V. J., Ameh, J. B. and Galadima, M. (2004). Hazards associated with kilishi preparation in Zaria, Nigeria. *Nigerian Journal of Microbiology*, 18(1-2):339–345.

Abubakar, S., Ribah, M. I. and Muftau, M. A. (2021). Effect of Some Natural Additives and Forms of Application on Organoleptic Properties of Fried Beef. *International Journal of Food Nutrition and Safety*, 12(1): 41-46.

Akinleye, S. B., Omojola, A. B. and Rashidat, K. O. (2018). Nutritional quality of *suya* prepared from mutton using different types of muscles. *Asian Food Science Journal*, 6(3): 1-8.

Akinola, T. O., Fatunmibi, O. O., Alake, O.T., Asagbra, A.E. and Onawola, O. O. (2019). Proximate and Mineral Composition of Locally Sourced Suya Spices Sold In Agege Area of Lagos State. *World Journal of Innovative Research*, 6(4): 49-54.

AOAC. Official Methods of Analysis (2000). 17th Edn., Association of Official Analytical Chemists, Washington, DC.

APHA (1992). Compendium of method for the microbiological examination of foods, 3rd edn Ame. Public Health Ass. In C. Vanderzant, & D. F. Splitsloesser (Eds.). Michigan, USA. Available:http://www.apha.org

Borch, E., Kant-Muermans, M.L. and Blixt, Y. (1996). Bacterial spoilage of meat and cured meat products. *International Journal of Food Microbiology*, 33(1): 103-120.

Cheesebrough, M. (2000). District laboratory practice in tropical countries. Part pp.76–100. Cambridge, UK: Cambridge University Press. pg

Effiong, G. S. and Udo, I. F. (2010). Nutritive Values ofFour Indigenous Wild Fruits In Southeastern Nigeria, *Electronic Journal Of Environmental, Agricultural And Food Chemistry*, 9(7): 1168-1176.

Hassan, E.L., Umar, F.I., Yahaya, S.F. and Ali, M. (2018). Microbial quality assessment of processed meat product (Tsire) sold within Wudil town, Wudil Local Government Area, Kano State, Nigeria. *Modern Applications in Pharmacy and Pharmacology*, 2(2), 1-7.

ICMSF (1996). International Commission on Microbiological Specifications for Food Microorganisms in Foods: *Microbiological Specifications of Pathogens*. 5: 89.

Igyor, M.A. and Uma, E.N. (2005). Bacterial Quality of a smoked meat product (Suya). *Nigerian Food Journal*,. 23: 233-242.

Inyang, C.U., Igyor, M. A, Uma, E. N. (2005). Bacterial quality of a smoked meat product (Suya). *Nigerian Food Journal*, 23(1):239–242.

Jayathilakan, K., Sharma, G. K., Radhakrishna, K. and Bawa, A. S. (2007). Antioxidant potential of synthetic and natural antioxidants and its effect on warmed-over-flavour in different species of meat. *Food Chemistry*, 105(3):908–16.

Kamala-Kumari, P. V., Akhila, S., SrinivasaRao, Y. and Rama-Devi, B. (2019). Alternative to artificial preservatives. *Systemic Review in Pharmacy*, 10: 13-16.

London Health Protection Agency (LHPA) (2009). Guidelines for Assessing the Microbiological Safety of Ready-to-Eat Foods Placed on the Market. 26.

Mandee, Q., Hassan, A. and Isa, Z. (2003). Antimicrobial activity of certain spice extracts. *Journal of Spice and Aromatic Crops*, 122: 146-153.

McCarthy, T. L., Kerry, P. J., Kerry, F. J., Lynch, B. P. and Buckley, J. D. (2001). Assessment of the antioxidant potential of natural food and plant extracts in fresh and previously frozen pork patties. *Meat Science*, 57: 177-184.

Nester, E. W., Aderson, D. G., Roberts, C. E., Pearsall, N. N. and Nester, M. T. (2001). Microbiology: A Human Perspective. Third Edition. Mc Graw Hill Company, U.S.A., 822-809.

Nwakanma, C., Unachukwu, M. N. and Momoh, O. R. (2015). Bacteriological examination of suya meat sold in Enugu metropolis. *World Journal of Pharmaceutical Research*, 4(12): 61-70.

Ochei, J. and Kolkhatkar, A. (2000). Medical laboratory science: Theory and practice. New Delhil, India: Tata McGraw-Hill.

Olaoye, J. O., Obajemihi, O. I. and Metiboba, T. C. (2016). Effects of processing methods and packaging materials on the quality attributes of Suya meat. *Ukrainian Journal of Food Science*, 4(2): 248-258.

Omojola, A. B. (2008). Yield and organoleptic characteristics of suya (an intermediate moisture meat) prepared from three different muscles of a matured bull. African Journal of Biotechnology, 7(13), 2254–2257.

Omojola, A. B., Isah, O. A., Adewumi, M. K., Ogunsola, O. O. and Attah, S. (2003). Evaluation of the effects of various additives on the acceptability of Kilishi. *Tropical Journal of Animal Science*, (2): 97-101.

Omojola, A. B., Kassim, O. R., Adewumi, M. K., Ogunsola, O. O., Adeyemo, G. O. and Adeshiyan, A. B. (2004). Evaluation of the effects of variation in ingredient composition on the eating qualities of suya. *African Journal of Livestock and Extension.* 3: 28-32.

Salihu, D. Y., Duru, S., Abdu, S. B., Munza, B. M., Abdu, M. B., Sadiq, A. A. and Bamus, O. A. (2020). Effect of breed, chilling duration and processed product on the quality characteristics of mutton. *Nigerian Journal of Animal Production*, 47(1):100 – 113.

SAS (1999). Statistical Analysis System Institutes. User's guide. SAS Institute Inc. Cary, N. C.

Sivasanker, B. (2005). Prentice-Hall of India Private Limited. *Food Processing and Preservation*, 1-360.

Zhang, X., Li, D., Meng, Q., He, C. and Ren, L. (2016). Effect of mulberry leaf extracts on color, lipid oxidation, antioxidant enzyme activities and oxidative breakdown products of raw ground beef during refrigerated storage. *Journal of Food Quality*, 39(3):159–70.