GSJ: Volume 7, Issue 10, October 2019, Online: ISSN 2320-9186

www.globalscientificjournal.com

Quality evaluation of *suya* prepared from two sources of heat (Gas and Charcoal)

Author's Full Names: AKINLEYE, SULE BAMIDELE*
Affliation of authors: Meat Science Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.
Corresponding Author's Email Address: bamideleakinleye@yahoo.com
Cellular phone number: +234-080-80735893; +234-081-42354621

Co-author's Full Names: AWODOYIN,OLAYEMI RASHDAT
Affliation of authors: Meat Science Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.
Email Address: kasyem@yahoo.com

ABSTRACT

Cooking increases the safety of food by inhibiting the growth of harmful microbes and increasing shelf-life. However, the type of heat a product is subjected to have a profound effect on the final product both chemically and physically. Suya is boneless meat of animals usually from beef that is stacked on sticks, sauced and oiled and then grilled over a glowing fire which is usually charcoal. The aim of this study is to assess the effect of different sources of heat on the nutritional and keeping qualities of suya.

A total of twenty-four Semitendinosus muscle was harvested from the carcasses of twelve fattened Balami rams; these were sliced into thin sheets and stacked into Suya stick. The weight of each stick before and after the meat was stacked was recorded. A total of 120 sticks of meat were prepared, randomly allotted to the two sources of heat. The final products were labeled Gas Suya (GS) and Charcoal Suya (CS), respectively. The average weight of the meat and stick together were between 14-17g. The raw meat with sauce and oil, GS and CS were subjected to analysis. The laboratory analysis includes cooking loss (CL), water holding capacity (WHC), product yield (PY) and chemical composition (CC) using AOAC methods, microbiological counts (log 102cfu/g cm^2) using the total aerobic count (TAC) method.

The results showed that CL (27.58±2.69%), was significantly higher (P=0.05) in CS, while WHC (87.53±6.90%) and PY (78.96±5.47) were significantly (P<0.05) higher in GS. The ash content (8.52±0.47%) of CS, the moisture (23.03±0.41%) and cholesterol (53.08±3.96%) contents of GS were significantly higher (P=0.05). The TAC (2.83±0.20) of CS was higher (P=0.05) than 1.30±0.20 of GS. The chemical and physical composition of GS are better than those of CS Suya, therefore, using gas in the grilling of Suya will be a great advantage to the producer and the consumer.

Keywords: *Suya*, heat, microbiological counts, gas, charcoal, cooking loss, water holding capacity, aerobic counts

Research article

Quality evaluation of mutton *suya* prepared from two sources of heat (Gas and Charcoal)

Sule Bamidele, Akinleye[*] and Olayemi Rashidat, Awodoyin

Corresponding Author's Email Address: bamideleakinleye@yahoo.com
Co-author Email Address: kasyem@yahoo.com
Meat Science Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

1. INTRODUCTION

Cooking increases the safety of food by inhibiting the growth of microorganisms, inactivating antinutrient enzymes, and increasing shelf-life. Additionally, it improves the organoleptic properties of meat [1, 2]. The source of heat used during cooking is a crucial factor in controlling and diminishing contamination in food products [3].

The fuel type used as source of heat and the temperature are the major contributors to contaminants of meat products [4, 5]. There is preferential consumption of different types of meat by people due to some factors such as religious belief, culture, food habits, and sex of the animal, age at slaughter, socio-economic factors, individual variation and income [6, 7]. In Nigeria, chevon is predominant among the South Easterners; pork is a slice of forbidden meat among the Northerner [7] while mutton consumption is mostly restricted to one of the festive periods among the Muslims.

Sheep have been among the first domesticated animals and are ranked the third among the domesticated ruminants for the production of meat and milk after cattle and buffaloes [8]. These animals offer an important source of wealth and continuing contribution of providing food for the growing world population [9]. However, potentials of mutton have not been fully explored especially in areas of value addition which can further increase its acceptance in various households.

Suya is one of the meat products that are popular especially in Nigeria and also in other African countries. It is a popular street delicacy of several countries, particularly those in West Africa [10]. It is a boneless, roasted, spicy ready-to-eat meat product usually prepared from beef, although other meat sources such as chevon, chicken, fish etc have also been used in preparing *Suya*. However, its production from mutton has received low attention.

The objective of this research was to: investigate the influence of different sources of heat on the physico-chemical properties, chemical composition, eating quality characteristics and keeping qualities of *Suya* produced from mutton.

2. MATERIALS AND METHODS

A total of twenty-four *Semitendonisus* muscles (ST) were harvested from the carcasses of twelve fattened Balami rams slaughter at the slaughterhouse of the Department of Animal Science, University of Ibadan. The ST muscles were cut into thin slices and randomly assigned to the two sources of heat (charcoal and gas).

2.1 Preparation of *Suya* Ingredients

The spices (raw) used in preparing the *suya* ingredient were purchased from spice stand unit at Bodija market (a commercial market). The spices include ginger (Zingiber officinales), black pepper (Piper guineense), red pepper (Capsicum fructescens). Roasted groundnut (Arachis hypogaea) and other seasonings (Monosodium glutamate) were also bought from the same market. The spices were dried, milled individually and kept in a dry container separately before mixing it together in a specific proportion as shown in Table 1 as developed in Animal Product Unit of the Department of Animal Science, University of Ibadan [11, 12].

Table 1: Percentage composition of Suya ingredient

Name of spices and Additives	Scientific names	%
Groundnut cake powder	(*Arachis hypogea*)	52.00
Ginger	(*Zingiber offinale*)	5.00
Garlic	(*Allium sativum*)	5.00
Red Dried pepper	*(Capsicum annuum)*	10.00
White pepper	(*Piper nigrum*)	5.00
Curry	(*Murraya koenigii*)	5.00
Salt	(*sodium chloride*)	8.50
Seasoning	(*monosodium glutamate*)	7.50
Groundnut oil		2.00
Total		100.00

Source: Omojola *et al.* (2004)
* 5-10 mls of groundnut oil was added to each stick of meat during roasting.

2.2 Preparation of *Suya*

The ingredient was spread on a clean, dry tray and each stick of meat was properly dusted with the ingredient (Omojola *et al.,* 2004). An individual *suya* stick, which was about 30 cm long, was weighed and the thin sheets of meat inserted into the *suya* stick. A total of 60 sticks of *suya* were prepared from each muscle type.

2.2.1Sticking of *Suya*

Individual *Suya* stick, about 30 cm long, was weighed and the thin sheets of meat inserted into the *Suya* stick and weigh again. The average weight of the meat per stick was between 33.67 to 43.16g. The formulated ingredient was spread on a neat flat tray and each stick meat was properly dusted with the ingredient [11]. The average weight of ingredient per stick meat was measured after proper coating with the ingredient. The average weight of ingredient per stick meat was between 4.64 and 7.35g. A total of 120 sticks of *Suya* were prepared and these were randomly allotted equally to the two heat sources (Charcoal and Gas) after which they are labeled, Charcoal *Suya* (CS) and Gas Suya (GS) for proper identification. Five to ten mills of groundnut oil was sprinkled on each *Suya* sample during grilling. The *Suya* was grilled for 25 minutes with intermittent turnings. The *suya* was allowed to cool down before the final weights were taken.

2.2.2 Grilling *Suya* with the charcoal heat source (CS)

A glowing smokeless fire was made from charcoal. Labeled *Suya* sticks of meat were arranged around the glowing charcoal fire. A distance of 20cm from the center of the fire and the *suya* sticks was maintained and the stick meats were turned intermittently. Groundnut oil was sprinkled on the meat while grilling continued [11]. The temperature of cooking was monitored by a thin chromium-aluminum thermometer and cooking terminated when the core temperature of the stuck meat reached the degree of doneness (78^{o}C to 80^{o}C). (This temperature was attained at around 20 minutes of cooking the meat). The products were removed from the fire and allowed to cool down at room temperature for thirty minutes and the final weights taken and recorded to determine the product/cooking yields and cooking loss. All necessary hygienic precautions were observed during the processing procedures.

2.2.3 Grilling *Suya* with the gas heat source (GS)

This was performed using a large preheated gas grilling machine. The sticks of meat were placed on a turntable rack, arranged approximately 20cm above the heating elements and turned intermittently during the twenty minutes of exposure to heat. The cooking was terminated when the internal core temperature of the stacked meat reached the degree of doneness (71^{o}C to 75 ^{o}C for grilling machine). After cooking the products were allowed to cool for thirty minutes and the weights were taken and recorded to determine the product/cooking yields and cooking loss. The products (CS and GS) were packaged separately in Low Density Polythene (LDPE) for subsequent analysis.

2.3 Quality Studies

2..3.1 Cooking loss (CL) and cooking /product yield (PY) percentages

Cooking loss was determined on raw meat samples before stacking it on the *suya* sticks. Chunks of meat were cut and weigh, these were put into polyethylene bags and labeled. The polyethylene was now put into boiling water (100ºC) and boiled for twenty minutes after which it was removed, allowed to cool at ambient temperature and the weight was taken. This was done in triplicates. Cooking loss percentage was determined by evaluating the differences in weight of the initial raw sample from a cooked sample and divided by the initial weight before cooking multiplied by 100.

Cooking/products yield were determined in *suya* samples in triplicates. This was determined using the method described by [13]. It was expressed as the percentage of the final weight of the product to the initial weight of raw samples of *suya*.

$$\%\ \textbf{cooking loss} = \frac{\text{Initial weight of the sample before cooking} - \text{weight of the sample after cooking}}{\text{Initial weight of the sample before cooking}} \times 100$$

$$\%\ \textbf{cooking/product yield (PY)} = \frac{\text{Weight of } \textit{Suya} \text{ after cooking}}{\text{Weight of } \textit{Suya} \text{ before cooking}} \times 100$$

2.3.2 Water holding capacity (WHC)

The WHC was determined with a press method according to [14]. An approximately 1g of a sample (*Suya*) was placed between two 9 cm Whatman No 1 filter papers (model C, Caver Inc, Wabash, U. S. A). The sample was pressed between two 10.2 x10.2 plexiglass for sixty seconds using a vice. Pressed samples were oven dried at 105°C for 24 hours and their moisture contents determined. Amount of water released from samples was measured indirectly by measuring the area of filter paper wetted relative to the area of pressed samples. This was done in triplicates for each of the cooking methods thus WHC of samples was calculated thus:

$$WHC = \frac{100 - (Aw - As) \times 9.47}{Ws \times Mc} \times 100$$

Where Aw = Area of water released from Samples (cm^2)
As = Area of Sample (cm^2)

Ws = Weight of Samples (g)
Mc = Moisture Content of Samples (%)
9.47 = Constant Factor

2.3.3 Shear force (SF) determination

This was determined by using the method described by [15] Shear test was performed using INSTRON 5965 with Warner-Bratzler shear force (WBSF) attachment. The WBSF was determined for Suya samples. Cylindrical samples, with the diameter of 1.27 cm and height of 2.5±0.3cm, were shear using a "V" shaped knife. The direction of cutting force was perpendicular to the muscle fibres orientation. The test was conducted with constant head speed (cell capacity 500 N) at 200 mm/ min, at a standardized temperature of the samples (2±1°C). This was done in triplicates for *suya* from each heat sources.

2.3.4 Colour

The colour of the mutton *Suya* samples were measured using a colorimeter (Minolta spectrophotometer CM 3500d, Japan). The colour reading ranges from redness, lightness, and yellowness.

2.3.5 pH determination

The pH of fresh mutton and mutton *Suya* samples were determined according to the method described by [16]. The pH was measured in an aqueous extract from 1g of the dried samples homogenized in 10 ml distilled water. The pH was measured using a pH meter (Lab tech digital 152R).

2.3.6 Chemical composition:

The chemical composition for moisture, protein, fat, and ash was determined according to the [17]. This was carried out both on the raw mutton and on the mutton *suya*. The crude protein contents were determined by the Kjeldahl method and the crude lipid contents were determined by the Soxhlet method. The ash contents were determined by subjecting the samples to high temperature (550ºC) inside the furnace overnight.

Percentage moisture contents were determined using the air oven method by drying 10 grams of raw mutton and *suya* samples at 105ºC to a constant weight. The difference in weight before and after drying divided by weight before drying multiplied by 100 was recorded.

2.4 Microbial analysis

The microbiological assessment of *Suya* was carried out using three parameters: Total Aerobic Counts (TAC), Total Coliform Counts (TCC) and Total Fungal Counts (TFC). The TAC of *suya* samples from the two heat sources were determined following aseptic technique procedure and following the method described by (7). Samples from each product (15 g) were taken aseptically and homogenized in 0.1% (w/v) peptone solution for one minute. The homogenate was serially diluted and used for microorganism enumeration and nutrient agar was used for total bacteria counts after 48 hours incubation at 37°C. The population of bacteria was expressed as log CFU g-1.

For TCC, the spread plate technique was used. One milliliter aliquot of each of the diluted samples was plated out on sterile MacConkey agar (MA). Incubation was at room temperature for 48 hours in an inverted position. Discrete colonies of coliform bacteria that developed were counted and recorded.

2.4.1 Preparation of Media for Fungi Isolation (TFC)

The media (Nutrient agar, Potato Dextrose Agar and MacConkey agar) were prepared according to the manufacturers‟ instruction. The associated fungi were isolated using a standard pour plate technique. Ten grams of the dried meat products were homogenized in sterile distilled water. One milliliter of the homogenate was decimally diluted and 1 ml of selected dilution (10^{-4}) was plated in duplicate on a sterile Sabouraud Dextrose agar containing 1% streptomycin. Inoculated plates were incubated at 28 ± 2°C for 5-7 days. Discrete colonies were isolated in pure culture by sub-culturing the cells [18].

2.4.2 Thiobarbituric Acid Reactive Substances (TBARS)

The rate of lipid oxidation was determined on the *suya* samples by measuring the amount of thiobarbituric acid reactive substances produced by the samples during storage (7 days). This was determined through the extraction methods process described by [19] and modified by [20].

2.5 Sensory evaluation

The panel consists of 25 students from the Department of Animal Science, University of Ibadan. A 9 point hedonic scale method which ranged from 1; dislike very much to 9; like very much - was used to evaluate colour, flavour, tenderness, juiciness and overall acceptability (1).

2.6 Statistical analysis

Data obtained were analyzed using one-way Analysis of Variance (ANOVA) and followed by DUNCAN Multiple range test of statistical package for social science version 15.0 [22] where there are statistical differences.

3. RESULTS AND DISCUSSION

3.1 Physical properties

The physical properties of *suya* prepared from different sources of heat are shown in Table 2. Cooking loss of *suya* samples from CHS (27.58±2.69%) and GHS (20.94±2.71%) were significantly different as the sources of heat and internal temperatures were not the same. Cooking loss measurement is a method used in assessing the impact of heat treatment on meat products because it is a reflection of the degree of its juiciness, as well as the product yield [23]. The differences obtained in the product yields of *suya* in this study contradicts the results obtained by [24] and [15] who observed no significant differences in the cooking yield of beef with the slow heat process. The results showed that product yield of *suya* samples from GHS (78.96±5.47%) was significantly (P=0.05) higher than that of *suya* samples from CHS (72.62±9.59%). The low product yield of samples obtained for CHS might be attributed to the excessive fat separation and water release during cooking as a result of the high and unregulated temperature. During the heat treatment, meat loses 20-40% of its total initial weight due to fluid leakage with the increasing temperature [25]. The higher product yield recorded for GHS could also be as a result of the high recipe uptake by most of the *suya* allotted to a GHS as indicated on the table. However, the result obtained for this study fall within the values of 21.27 to 33.36% reported by [26] for meat products.

The SF and pH of *suya* samples from CHS (3.91±0.23 and 5.97±0.01kg/cm^2) were significantly (P=0.05) higher than that of *suya* samples from GHS (3.11±0.46 and 5.86±0.02kg/cm^2). Warner-Bratzler shear force is an objective measure of tenderness used in the research laboratory to evaluate relative differences in tenderness or toughness of meat products. From the results, it was observed that products prepared from the GHS have a high water holding capacity compared to a product prepared from the CHS. This implies that *suya* samples from GHS will retain more water which might make it tender and soft during mastication compared with products from CHS which is drier due to the less water retained. The meat pH has a great impact on three sensory quality characteristics of meats: appearance, texture and flavour; and all these affect the consumer acceptance of meat [27]. Such differences could be caused by the differences in the organic acid content of the raw materials used as the sources of heat [28]. The pH of the *suya* in this study was in line with the research which stated that the water content of meat thermally treated was lower than the raw meat [11].

Water holding capacity, reported as percentage expressible juice, was 87.53±6.90% for the *suya* samples from GHS and 67.94±7.95% for the CHS samples, all of which were significantly different from each other. The water holding capacity of meat is of great importance in the meat industry, as it affects the chemical composition, economic and sensory attributes of meat [26, 29 and 30]. The treatment using charcoal led the protein of meat to bind more volatile compound, thus, it could not bind much water. A volatile compound of CHS was lower than that of GHS. Generally, cooking contributes to the loss of water-holding capacity, resulting in the concentration of proteins, fat, and ash in meat products [10] and meat [31]. Prolonged heat treatment caused tenderness loss in the products of CHS. This can be explained by the significant content of connective tissue in the muscle [13]. High temperature and prolonged heating affect the tissue, which in turn influences hardness of the product since changes in the cutting force are closely related to the myofibrils contraction and degree of collagen denaturation [32].

Table 2: Physical properties of *Suya* prepared from two different sources of heat

	Sources of Heat		
Parameters (%)	Charcoal	Oven	P value
Recipe uptake	16.24±4.89	19.68±3.90	0.1458
Cooking loss	27.58±2.69[a]	20.94±2.71[b]	0.0001
Cooking /Product yield	72.62±9.59[b]	78.96±5.47[a]	0.0710
Shear force kg/cm^2	3.91±0.23[a]	3.11±0.46[b]	0.0001
Ph	5.97±0.01[a]	5.86±0.02[b]	0.0001
Water Holding Capacity	67.94±7.95[b]	87.53±6.90[a]	0.0001

[a,b,c] :Means with different superscripts in the same row differ significantly (P<0.05)

3.2 Chemical Composition of *Suya*

The changes in moisture, protein, fat, and ash contents of raw mutton before and after cooking are shown in Table3. The moisture content of mutton before cooking is 70.87±0.24g/100g, decreased after cooking. Raw mutton had the lowest protein content (20.79±0.25g/100g), while the cooked samples had the highest (49.50±0.05 and 49.44±1.06g/100g). The results indicated that sources of heat affected the protein content of cooked meat but was not significantly different. Denaturation of protein occurred during the heating [33, 34]. The values obtained for crude protein, ash, fat contents of *suya* in this study were higher than that reported by [35] and [18]. Raw mutton contained a higher level of moisture compared to cooked samples. The moisture content of raw mutton samples found to be inversely related to the total lipid content. This could be attributed to the oil penetration on the food after water is evaporated during cooking [36]. Generally, the protein and ash contents increased after cooking in all evaluated methods (P=0.05). According to [37], increase in protein, fat, and ash contents could be explained by the reduction in moisture. The fat content of cooked meat was higher than raw; samples from CHS and GHS were similar with our results which stated that the fat content of meat thermally treated was higher than the raw meat [11].

Table 3: Chemical compositions of raw and freshly prepared s*uya* produced from mutton using two sources of heat

	Raw mutton	**Mutton *Suya***		
		Sources of **Heat**		
Parameters (%)		Charcoal	Oven	Pvalue
Moisture Content	70.87±0.24[a]	22.46±0.42[c]	23.03±0.41[b]	0.0001
Crude Protein	20.79±0.25[b]	49.50±0.95[a]	49.44±1.06[a]	0.0001
Ether Extract	6.25±0.17[b]	18.04±0.46[a]	18.05±0.67[a]	0.0001
Ash	2.09±0.08[c]	8.52±0.47[a]	7.98±0.41[b]	0.0001

[a,b,c] :Means with different superscripts in the same row differ significantly (P<0.05)

3.3 Sensory Evaluation of *Suya*

Table 4 showed the results of mean organoleptic properties of *suya* samples. The results indicated that there were significant (P=0.05) differences in organoleptic properties of s*uya* samples. *Suya* colour (6.70±0.28), juiciness (7.10±0.71) and tenderness (7.00±0.7) were significantly higher (P=0.05) in *suya* samples from GHS than CHS while *suya* samples from CHS was adjudged the most (P=0.05) flavoured (6.50±0.71). However, Similar results were obtained for hotness and acceptability. In general, the most preferable colour of *suya* is golden brown which depends on the non-meat ingredients, meat components and heating process. Also, there were Maillard reaction and caramelization as well as changes of myoglobin of meat during processing together with the present of non-meat ingredients. According to [38] hotness and acceptability were statistically not significant difference.

Table 4: Eating qualities of freshly prepared s*uya* produced from two different sources of heat

	Sources of Heat		
Parameters	Charcoal	Oven	Pvalue
Colour	4.10±0.41[b]	6.70±0.28[a]	0.0086
Flavour	6.50±0.71[a]	6.22±0.12[b]	0.2859
Juiciness	6.40±0.71[b]	7.10±0.71[a]	0.0171
Tenderness	6.30±0.71[b]	7.00±0.71[a]	0.1121
Hotness	5.20±0.28	6.42±0.46	0.2524
Overall acceptability	6.40±0.71	7.30±0.71	0.1253

[a,b,c] :Means with different superscripts in the same row differ significantly (P<0.05)

3.4 Microbiological characteristics of *suya* prepared from different sources of heat

Table 5 showed the results of microbiological analysis of *suya* prepared from different sources of heat. The results of microbiological analysis showed that the total aerobic aerobic counts was 2.83±0.20Log (cfu/g) and 1.30±0.20Log (cfu/g) for *suya* samples from CHS and GHS, respectively. The differences in these values were statistically significant (P=0.05). Total coliform and Total fungal counts (Logcfu/g) were 4.20±0.20 and 4.40±0.20 in *suya* samples from CHS, respectively while 7.30±0.20 and 3.10±0.20Log (cfu/g) in *suya* samples from GHS, respectively. Significant differences (P<0.05) were observed between the mean microbial counts in *suya* samples at day-seven. The levels of microbial loads in different *suya* samples did not exceed the recommended value of 5.48 Log (cfu/g). A low microbial content of these samples could be due to the low moisture content, proper handling, spices and non-meat ingredients and water activity value of samples. TBARS content is commonly evaluated to determine lipid oxidation which is related to meat quality [39]. TBARS were not signicantly different between the experimental samples in the present study, probably due to the absence of differences in PUFA-content of meat samples [40, 27].

Table 5: Microbiological counts (log 10^2cfu/g cm^2) and Thiobarbituric Reactive Substances (TBARS) (mgMDA/100g) of mutton *Suya* produced from two heat sources after storage for 7 days

	Sources of Heat		
Parameters	Charcoal	Oven	Pvalue
Total Aerobic Count	2.83±0.20[a]	1.30±0.20[b]	0.0001
Total Coliform Count	4.20±0.20[b]	4.40±0.20[a]	0.0001
Total Fungal Count	7.30±0.20[a]	3.10±0.20[b]	0.0001
TBARS	0.21±0.02	0.22±0.04	0.0001

[a,b,c] :Means with different superscripts in the same row differ significantly (P<0.05)

Conclusion

On comparing the *suya* samples from CHS and GHS, the results indicated that GHS had considerable effect on the proximate composition of *suya* samples. Based on the results obtained for physical properties, proximate, sensory and microbiological properties, the GHS of *suya* samples were found to be the best among the sources of heat for healthy eating.

Competing Interests

Authors have declared that no competing interests exist.

References

1 Suzuki, A, Koima, N and Ikeuchi, Y. (1991): Carcass composition and meat quality of Chinese purebred and European X Chinese crossbred pigs. *Meat Science*.; 29: 31 – 41.

2 Carmody RN, Weintraub GS, Wrangham W. (2011): Energetic consequences of thermal and nonthermal food processing. Proc Natl Acad Sci; 108(48):19199–203.

3 Pikul J, Leszizynski DE and Kummerow FA. (1984): Relative role of phospholipids, triacylglycerides and cholesterol esters on malonaldehyde formation in fat extracted from chicken meat. *Jour. Food Sci.*; 49:704-708

4 Chung SY, Yettella RR, Kim JS, Kwon K, Kim MC, Min DB. (2011): Effects of grilling and roasting on the levels of polycyclic aromatic hydrocarbons in beef and pork. Food Chem; 129(4):1420–6.

5 SPSS/PC. (1986): Manual for SPSSPC+ for the IBM PC/XT/AT. SPSS Inc., Chicago, IL.USA

6 Ajiboye E, Alhassan S, Adedayo R, Majekodunmi M, Kolawole M, Olatunji O and Oladosu T. (2011): Physicochemical properties and microorganisms isolated from dried meat obtained in Oja-Oba market in Ilorin, Nigeria (Pelagia Research Library) *Advances in Applied Science Research*.; 2 (4):391-400.

7 Offer, G.and Trinick, J. (1983): On the mechanism of water holding in meat: The swelling and shrinking of myofibrils. *Meat Sci*.; 8: 245- 281.

8 Marimuthu K Thilaga M, Kathiresan S, Xavier R, Mas, RHMH. (2011): Effect of Different Cooking Methods on Proximate and Mineral Composition of Striped Snakehead Fish (Channa Striatus, Bloch). Journal of Food Science and Technology; 16, 173–176.

9 Listrat A, Lebret B, Louveau I, Astruc T, Bonnet M, Lefau- cheur L, Picard B and Bugeon J. (2016): How muscle structure and composition influence meat and flesh quality. Sci. World. J.; 3182746.

10 Modzelewska-Kapitula M, Dabrowska E, Jankowska B, Kwiatkowska A, Cierach M. (2012): The effect of muscle, cooking method and final internal temperature on quality parameters of beef roast. Meat Sci.; 91 : 195 – 202.

11 Megahed GA and Etman AHM (2006): Effects of agricultural byproducts in ration on productive and reproductive performance of Saidi rams. Acta Veterinaria,; 75: 22–27.

12 Apata ES, Kuku IA, Apata, OC and Adeyemi KO. (2013):Evaluation of *Suya* (*Tsire*) – An Intermediate Moisture Meat Product in Ogun State, Nigeria. *Jour. Food Research*; 2 (1): 87-93

13 Kondjoyan A, Oillic S, Portanguen S, Gros JB. (2013): Combined heat transfer and kinetic models to predict cooking loss during heat treatment of beef meat. Meat Science; 95, 336e34

14 Purslow, PP, Oiseth SK, Hughes JM, Warner RD. (2016): The structural basis of cooking loss in beef: variations with temperature and ageing. Food Research International; 89, 739e748.

15 Stumpe-Vıksna I, Bartkeviˇcs V, Kukare A, Morozovs A. (2008): Polycyclic aromatic hydrocarbons in meat smoked with different types of wood. Food Chem; 110(3):794–7.

16 Bendall, JR. In: Bourne GH. (Ed). (1973): *Structure and function of muscle*, Academic Press, New York, 2nd Edition.; 2(2): 243-309.

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

18 Gandi, BR. (2014): Quality characteristics and microbial status of beef smoked with different plant materials and suya produced from round muscles. A thesis submitted to the school of post graduate studies, ahmadu bello university, zaria, nigeria in partial fulfilment of the requirements for the award of a masters of science degree in Animal Science.; Pp1-94

19 Ogunwole, OA and Adedeji,BS. (2014): Consumers' Preference and Perception of the different Types of Meat among Staff and Students of the University of Ibadan, Nigeria. *Jour. Agric. Environ. Sci.* 2014; 3(2) : 77-95

20 Pettipher GL. (1999): Microbiological Analyses, Advances in Milk Products. In: Modern Dairy Technology, Robinson, R.K. (Ed.). 2nd Edn., Vol. 2, Champman and Hall, New York,; pp: 441-460.

21 Abdullah, A. (2000): Panduan makmal penilaian sensori Penerbit Universiti Kebangsaan
Malaysia.

22 Raharjo, S. (2006): Oxidative damage in Food. Gadjah Mada University Press, Yogyakarta (2006).

23 Bertram, HC, Engelsen, SB, Busk, H, Karlsson AH and Andersen HJ. (2004): Water properties during cooking of pork studied by low-field NMR relaxation: effects of curing and the RN-gene. *Meat* Sci.; 66: 437-446.

24 Rosimini MR, Perlo F, Perez- Alvarez JA, Pagan-Moreno MJ, Gagogago A., Lopez-Santoveóa F, Aranda-Catâlel V. (1996): TBA test by extractive method applied to 'Pâte'. *Meat Sci*.; 42(1):103-110

25 Thippareddi Hand Sanchez M. (2006): Thermal Processing of Meat Products. In : Thermal Food Processing : New Technologies and Quality Issues. CRC Press. Taylor and Francis Group, Boca Raton (2006).

26 Kembi SO and Okubanjo AO. (2012): Physicochemical and sensory properties of dehydrated beef patties containing soybean products Trop. Anim. Prod. Invest 2012; (5). 137-148.

27 Momenzadeh Z, Khodanazary A, Ghanemi K. (2017): Effect of different cooking methods on vitamins, minerals and nutritional quality indices of orange-spotted grouper (Epinephelus coioides). J Food Measur Character ; 11(2):434–41.

28 Gonulalan ZA, Kose, Yetim H. (2003): Effect of liquid smoke on quality characteristics of Turkish standard smoked beef tongue. Meat Sci.; 66 : 165-170.

29 Jensen IJ, Dort J and Eilertsen KE. (2014): Proximate composition, antihypertensive and antioxidative properties of the semimembranosus muscle from pork and beef after cooking and in vitro digestion. Meat Sci; 96(2 Pt A):916–21.

30 Omojola AB, Adesehinwa AOK, Madu H, Attah S. (2004): Effect of sex and slaughter weight on broiler chicken carcass. J. Food Agri. Environ.; 2(3-4):61-63.

31 Kadim IT and Mahgoub O Nutritive value and quality characteristics of goat meat. In O. Mahgoub., I. T Kadim. And E. Webb. (2012): Goat meat production and quality; (pp 292-323) Wallimgford CABI

32 García –Segovia P, Andres-Bello, A, Martinez-Monzo, J. (2014): Effect of cooking methods on mechanical properties, colour and structure of beef muscle (*M. pectororalis). Jour. Food Engineer.* 2014; *80 (3): 813-821*

33 Rey-Salgueiro L, Garcia-Falcón MS, Soto-Gonzalez B, Simal-Gándara J (2009): Occurrence of polycyclic aromatic hydrocarbons and their hydroxylated metabolites in infant foods. Food Chem., 2009; 115: 814-819.

34 Onuorah S, Obika F, Odibo F. and Orji M. (2015): An Assessment of the Bacteriological Quality of Tsire-Suya (Grilled Beef) sold in Awka, Nigeria. *American Jour Life Sci.* 2015; 3(4) 287-292.

35 Huda, NY. Fatma, A. Fazillah and F. Adzitey, (2012): Chemical composition, colour and sensory characteristics of commercial serunding (Shredded Meat) in Malaysia. Pak. J. Nutr., 201;.11: 1-4.

36 Mapiliyao L, Pepe D, Marume U and Muchenje V. (2012): Flock dynamics, body and weight variation in sheep in two ecologically different resource-poor communal farming systems. Small Rumin. Res.; 104:45-54.

37 Ersoy B, Ozeren A. (2009): The effect of cooking methods on mineral and vitamin contents of African catfish. Food Chem; 115:419–422

38 Hughes, JM, Oiseth SK, Purslow PP, Warner RD. (2014): A structural approach to under- standing the interactions between colour, water-holding capacity and tenderness. Meat Science; 98, 520e532.

39 P´erez Palacios T, Caballero D, Bravo S, Bel JM, Antequera T. (2017): Effect of cooking conditions on quality characteristics of confid cod: prediction by MRI. Intl J Food Eng; 13(8). https://doi.org/10.1515/ijfe-2016-0311.

40 Li CB, Zhou GH, and Xu XL. (2013): Dynamical changes of beef intramuscular connective tissue and muscle fiber during heating and their effects on beef shear force. Food Bioprocess Technology; 3, 521-527.